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In This Issue

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Experimental Methods of Determining Optimum Operating Conditions — Part II-3

Top Management Decision Making

Economics of Quality

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QUALITY CONTROL

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From the President's Desk

Technometrics

With this issue of *Industrial Quality Control* the Society announces the publication, jointly with the American Statistical Association, of a new technical journal to be known as *Technometrics*, a journal of statistics for those concerned with the physical, chemical, and engineering sciences. This announcement marks the end of a period of exploration and preliminary planning for co-sponsorship of such a publication, unique in the field of technical journals, and hails the beginning of significant progress in the cooperative efforts of two professional societies in related fields of interest.

To the Chemical Division of ASQC goes considerable credit for initiating and spark-plugging this endeavor. In the past two years the Division people have worked diligently towards this goal, creating and stimulating interest in the project, and importantly, sponsoring activities that have provided the financial support required to launch this publication and to sustain it during its early life. Thus, the Division's part in this endeavor is substantial and speaking for the officers and directors, I express gratitude for this outstanding contribution to furthering the objectives of the Society.

Administration of *Technometrics* will be under the direction of a Management Committee composed of representatives of the sponsoring organizations, three from each, in addition to a chairman appointed jointly by the presidents. We are fortunate indeed to have for the important post of chairman the services of Dr. Paul S. Olmstead, a Fellow of both societies and currently a director of ASQC. Advisory to the Management Committee will be the editor of the Journal of the American Statistical Association, Prof. W. Allen Wallis, and the chairman of the Editorial Board of ASQC, Prof. Mason E. Wescott.

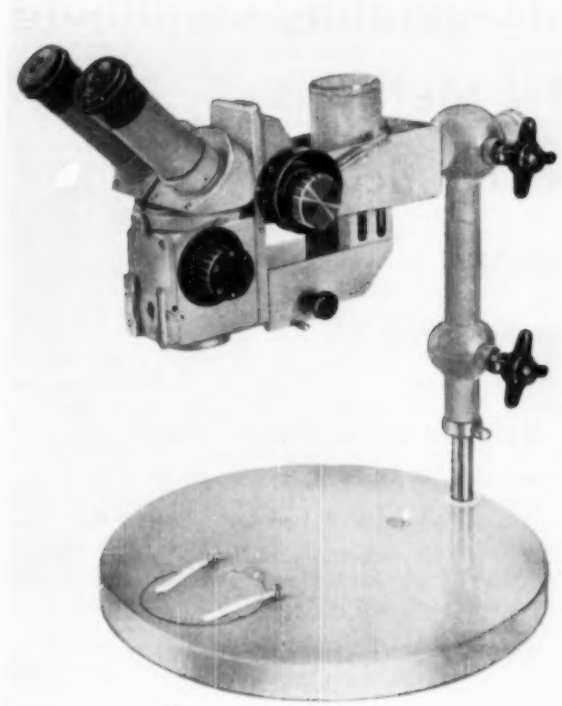
The Committee has appointed Dr. J. Stuart Hunter as editor of *Technometrics*. Dr. Hunter, who has been very active in the exploratory work, is with the Statistical Techniques Research Group, Princeton University, and brings to the project enthusiasm and talent that bodes well for its success. He will have working with him a number of associate editors to assist in the editorial work.

Technometrics will be a quarterly, to be published in the months of February, May, August and November, and will be available at a modest subscription rate. This rate will be somewhat less for members of the two societies than for non-members. In line with the conservatism of the two organizations, *Technometrics* will have a modest beginning, for the first year being confined to approximately 100 pages for each issue. It is hoped and expected that as the journal gains acceptance and circulation its size will likewise be increased.

Those of us in ASQC who have had some part in this project to date are grateful for the fine cooperative spirit shown by all in resolving some of the difficult problems involved. Particularly do I wish to express the thanks of our Society to Dr. Walter E. Hoadley, Jr. who was president of the American Statistical Association last year and who gave substantial support to this effort. Dr. Hoadley, Dr. Rensis Likert, president of ASA, and I are convinced of the merits of *Technometrics* and believe that it will be of interest and value to many members of our societies. We believe, also, that the project will be successful in its contribution to the technology and will serve as further evidence of the cooperative efforts of two important societies in our industrial community. I know that I speak for the officers, directors, and members of ASQC when I extend full support of the Society to the Management Committee, the editor, and his associates in this undertaking.

I urge that you consider seriously the addition of *Technometrics* to your personal library of technical journals.

C. E. Fisher



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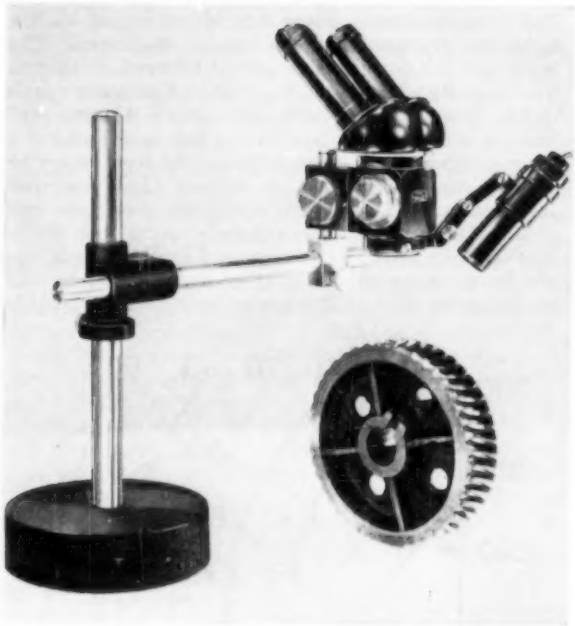

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Determination of Optimum Operating Conditions by Experimental Methods Part II-3, Models and Methods

J. STUART HUNTER

*American Cyanamid Company, New York, N. Y.**

Editorial Note

This is the third and final installment of Dr. Hunter's part of the major article. The article began in the July 1958 issue of *Industrial Quality Control*. The first installment by Dr. Hunter appeared in the December 1958 issue and the second installment appeared in the January 1959 issue.

Second Order Models

Experimenters are often required to describe a response as a function of several controlled variables over quite a wide range of these variables. An empirical understanding of the relationship is obtained if the experimenter can actually construct the contour lines describing the form of the response surface. For example, there is a wealth of information made available by the contour diagrams shown in Figures 11 and 12.†

On other occasions an experimenter or development worker may be asked to find a region which is optimum, not with respect to a single response, but with respect to two or more responses considered simultaneously. One interesting device for finding points or regions that are optimum with respect to several responses is to superimpose the contour diagrams of the responses. For example, imagine the response illustrated by the contours in Fig. 11 indicate the yield of product A, and the response illustrated in Fig. 12 indicate the yield of some simultaneously produced product B. By superimposing these two contour diagrams, as shown in Fig. 14, one can determine the settings of time and temperature which will simultaneously give, say, a yield of 90 for A and a yield of 80 for B.

Finally, in exploring a response an experimenter may first try to determine the nature of the response surface by fitting a first order model (a plane) to the responses. If no significant lack of fit exists then response surface can be illustrated by a set of parallel straight line contours or planes (or hyperplanes). Very often however the first order approximation will be found to be inadequate to represent the data. Under these circumstances the experimenter may then wish to represent the unknown response function by a second order model.

The second order model in two dimensions is

$$y = \beta_0 x_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_{11} x_1^2 + \beta_{22} x_2^2 + \beta_{12} x_1 x_2 + \varepsilon \qquad (27)$$

This is a very versatile mathematical model. Imagine for the moment that the coefficients in the model have been estimated, that is we have the *fitted* equation

$$\hat{y} = b_0 + b_1 x_1 + b_2 x_2 + b_{11} x_1^2 + b_{22} x_2^2 + b_{12} x_1 x_2 \qquad (28)$$

Now set $\hat{y}$ equal to some constant, say $\hat{y} = 80$. The resultant expression can be the equation of a circle or an ellipse, hyperbola, parabola or even a straight line. The actual geometric shape depends, of course, on the signs and magnitudes of the various coefficients. The important fact to remember is that everywhere on this line, regardless of its form, the predicted response equals eighty. It should be quickly appreciated that the contours of a response surface having the appearance of a mound, or valley, or rising ridge can be represented by sets of concentric circles, or ellipses. Saddle shaped responses will produce contours having the appearance of sets of hyperbolas. Thus any response function whose true contours take the appearance of gently curved lines can be approximated over rather wide regions by this second order model. There may be of course multiple

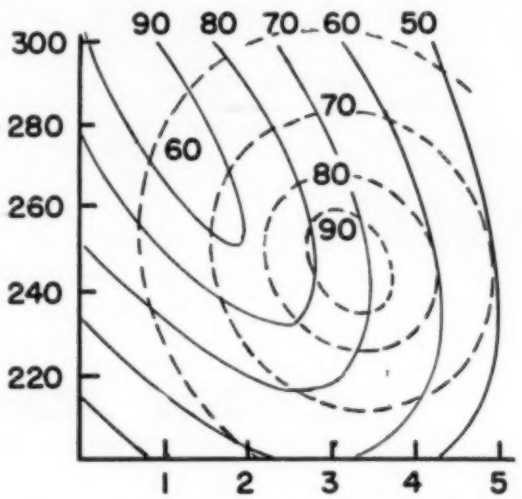

Figure 14 (- - - Contours for Product A; — Contours for Product B)

*Presently with the Statistical Techniques Research Group, Princeton University.

†See page 14, January 1959 issue of *Industrial Quality Control*.

"hill and dale" response surfaces, or surfaces with unusual breaks in overall smoothness. A second order model cannot be expected to fit these responses.

Fortunately, most practical experience indicates that these response surfaces are the exception rather than the rule. More thorough descriptions of the application of fitted second order models to contour mapping are given in the following references: (1), (4), (5), (6), (7).

Second Order Experimental Designs

Estimating the six coefficients in the second order model given in (27) can become awkward computationally if care is not taken beforehand in selecting the levels of the controlled variables. One experimental design (not a "rotatable" design) that can be used to reduce this labor of computation is the three level factorial design. This design requires that each of the controlled variables be held a high (+1), middle (0), and low (−1) level, and that all combinations of levels and variables be run. Thus the number of experiments required is $N = 3^k$, where k equals the number of controlled variables. There are methods for fractionating the 3^k factorial designs to reduce the number of experiments. The co-ordinates of a two-dimensional, three-factor factorial design are (see Fig. 15)

Experimental Design Levels of a 3^2 Factorial Design

x_1	x_2
−1	−1
0	−1
1	−1
−1	0
0	0
1	0
−1	1
0	1
1	1

Although this array of points will greatly simplify the calculations required for estimating the coefficients in a second order model, the design suffers from one major statistical handicap. Up to this time nothing much has been said about predictions made on the basis of the fitted models, in particular about the confidence intervals that can be placed around the predicted response $\hat{y}$ for any fixed setting of the independent variables. Time cannot be taken here to develop this subject. However, the 3^k factorial designs do *not* give equal predictive power at a constant distance from the center of the design in all orientations. The design is therefore called "non-rotatable". An experimental design possessing equal predictability in all directions from the center of the design at a constant distance from the center is called a "Rotatable" design. The first order designs described earlier are all rotatable designs. Rotatable experimental designs have recently been developed for estimating all the coefficients in a second order model. The meaning of rotatability is described in more detail in the article "A Discussion on Rotatable Designs" by J. S. Hunter in the *ASQC Transactions, 1958;*[14] and again in a more theoretical article by G. E. P. Box and J. S. Hunter, "Multifactor Experimental Designs," *Annals of Mathematical Statistics,* Vol. 28, 1957.[5]

The simplest second order rotatable design in k = 2 dimensions is provided by the vertices of a pentagon with one or more points at the center of the design as illustrated in Fig. 16.

Coordinates of Pentagon Design

x_1	x_2
1.000	0
0.309	0.951
−0.809	0.588
−0.809	−0.588
0.309	−0.951
0	0

Replicating the point at the center of the design does not increase the number of degrees of freedom available for estimating the coefficients in a second order model. However, this replication of an experimental point provides an estimate of experimental error and should always be performed. It is of course wise to replicate the entire design. In any event, to ensure good predictability toward the center of the design, the center point should be replicated more frequently than the peripheral points.

All the regular figures in two dimensions having five or more vertices, each with at least one center point, provide second order rotatable designs. The choice of one design over another is usually determined by the number of trials the experimenter wishes to run, and by the number of levels he must maintain for each variable.

It is also important to remember that the experimenter, in attempting to understand better the nature of the unknown response function, is likely to begin with a first order model and a first order design. If he finds this approximation to the function inadequate he may then proceed to augment the original experimental design by additional points. Fortunately, as will be seen in the later sections, first order designs can be augmented to form rotatable second order designs. Good experimental strategy requires, in almost all cases, the

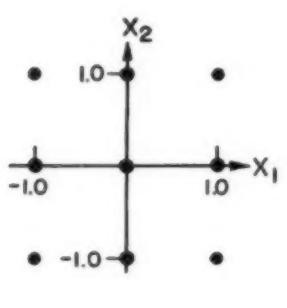

Figure 15

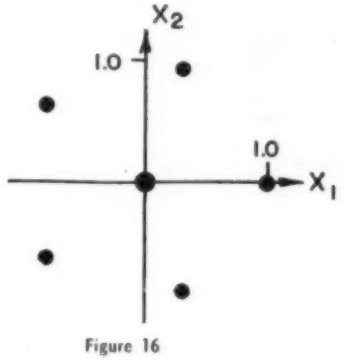

Figure 16

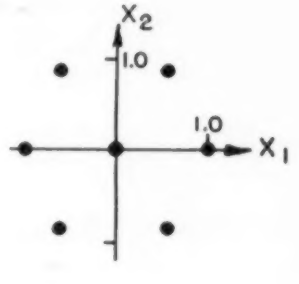

Figure 17

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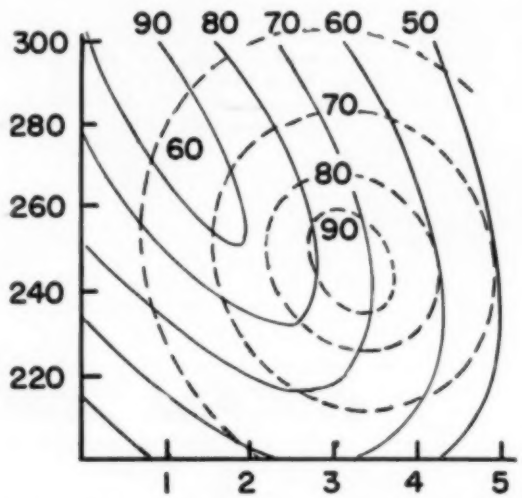

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0	1
1	1

Although this array of points will greatly simplify the calculations required for estimating the coefficients in a second order model, the design suffers from one major statistical handicap. Up to this time nothing much has been said about predictions made on the basis of the fitted models, in particular about the confidence intervals that can be placed around the predicted response $\hat{y}$ for any fixed setting of the independent variables. Time cannot be taken here to develop this subject. However, the 3^k factorial designs do *not* give equal predictive power at a constant distance from the center of the design in all orientations. The design is therefore called "non-rotatable". An experimental design possessing equal predictability in all directions from the center of the design at a constant distance from the center is called a "Rotatable" design. The first order designs described earlier are all rotatable designs. Rotatable experimental designs have recently been developed for estimating all the coefficients in a second order model. The meaning of rotatability is described in more detail in the article "A Discussion on Rotatable Designs" by J. S. Hunter in the *ASQC Transactions, 1958;*[14] and again in a more theoretical article by G. E. P. Box and J. S. Hunter, "Multifactor Experimental Designs," *Annals of Mathematical Statistics,* Vol. 28, 1957.[5]

The simplest second order rotatable design in k = 2 dimensions is provided by the vertices of a pentagon with one or more points at the center of the design as illustrated in Fig. 16.

Coordinates of Pentagon Design

x_1	x_2
1.000	0
0.309	0.951
−0.809	0.588
−0.809	−0.588
0.309	−0.951
0	0

Replicating the point at the center of the design does not increase the number of degrees of freedom available for estimating the coefficients in a second order model. However, this replication of an experimental point provides an estimate of experimental error and should always be performed. It is of course wise to replicate the entire design. In any event, to ensure good predictability toward the center of the design, the center point should be replicated more frequently than the peripheral points.

All the regular figures in two dimensions having five or more vertices, each with at least one center point, provide second order rotatable designs. The choice of one design over another is usually determined by the number of trials the experimenter wishes to run, and by the number of levels he must maintain for each variable.

It is also important to remember that the experimenter, in attempting to understand better the nature of the unknown response function, is likely to begin with a first order model and a first order design. If he finds this approximation to the function inadequate he may then proceed to augment the original experimental design by additional points. Fortunately, as will be seen in the later sections, first order designs can be augmented to form rotatable second order designs. Good experimental strategy requires, in almost all cases, the

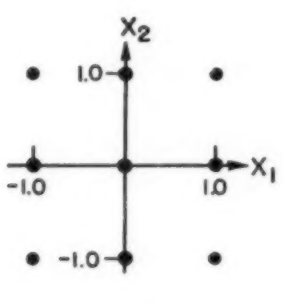

Figure 15

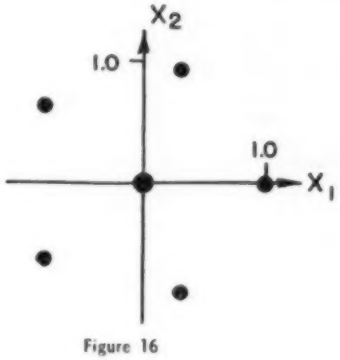

Figure 16

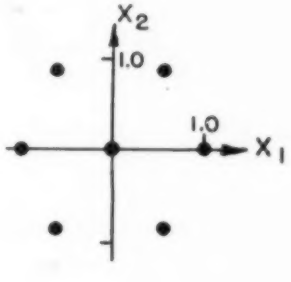

Figure 17

sequential construction of a second order model and its associated second order design.

The Hexagon and Octagon Designs

For k = 2 controlled variables a particularly valuable second order rotatable design is provided by the vertices of a hexagon with one or more points at the center of the design. A problem illustrating the use of the hexagon design is given below. This design requires that x_1 be held at five equally spaced settings and that x_2 be held at three equally spaced settings. The particular orientation of the hexagon design illustrated in Fig. 17 (or of any rotatable design) need not be fixed, the design may be rotated to any position without effecting its predictive power at any fixed point. For practical considerations however the hexagon design is usually oriented so that it does provide equally spaced settings along both axes. It is of course assumed that the controlled variables can be fixed at *any* level without error. This idealized situation is never reached and by equally separating the factor levels the hazards of the shading together of two close settings of a controlled variable are avoided.

Another very useful two dimensional second order design is the octagon design formed from the eight vertices of an octagon with one or more points at the center as illustrated in Fig. 20. It will be noted that this design closely approximates the 3^2 factorial except that some of the points have been extended until they lie on the sample circle as the $(\pm 1, \pm 1)$ points.

A Worked Example: The Hexagon Design

Suppose an experimenter wishes to explore the relationship of the yield of a chemical process to the temperature of the reacting mass, and to the rate of addition of the reagents. The experimental area of interest to the experimenter is contained in a temperature interval of 15 to 75 degrees centigrade, and a time interval of reagent addition of one to three hours. The coding mechanism adopted to relate the factor levels to the coordinate system of the experimental design are

$$x_1 = \frac{\text{Temp} - 45}{30^\circ}; \quad x_2 = \frac{\text{Addition Rate in Hours} - 2}{1.000}$$

The factor levels and associated levels of the design variables x_1 and x_2 are given below:

Factor Levels		Design Levels	
Temp (°C)	*Time (hours)*	x_1	x_2
75	2.0	1.000	0
60	2.866	0.500	0.866
30	2.866	−0.500	0.866
15	2.0	−1.000	0
30	1.134	−0.500	−0.866
60	1.134	0.500	−0.866
45	2.0	0	0
45	2.0	0	0
45	2.0	0	0
45	2.0	0	0

The mathematical model proposed is:

$$y = \beta_0 x_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_{11} x_1^2 + \beta_{22} x_2^2 + \beta_{12} x_1 x_2 + \varepsilon$$

The matrix of independent variables and vector of observations are:

Run No.*	Vector of obs.	Matrix of Independent Variables (2nd Order Model)					
	$y(\%)$	x_0	x_1	x_2	x_1^2	x_2^2	x_1x_2
1	96.0	1	1.000	0	1.000	0	0
2	78.7	1	0.500	0.866	0.250	0.750	0.433
3	76.7	1	−0.500	0.866	0.250	0.750	−0.433
4	54.6	1	−1.000	0	1.000	0	0
5	64.8	1	−0.500	−0.866	0.250	0.750	0.433
6	78.9	1	0.500	−0.866	0.250	0.750	−0.433
7	97.4	1	0	0	0	0	0
8	90.5	1	0	0	0	0	0
9	93.0	1	0	0	0	0	0
10	86.3	1	0	0	0	0	0

Doolittle Solution for the Coefficients (in general)

N	Σx_1	Σx_2	Σx_1^2	Σx_2^2	Σx_1x_2	Σy	(0y)
	Σx_1^2	Σx_1x_2	Σx_1^3	$\Sigma x_1x_2^2$	$\Sigma x_1^2x_2$	Σx_1y	(1y)
		Σx_2^2	$\Sigma x_1^2x_2$	Σx_2^3	$\Sigma x_1x_2^2$	Σx_2y	(2y)
			Σx_1^4	$\Sigma x_1^2x_2^2$	$\Sigma x_1^3x_2$	Σx_1^2y	(11y)
				Σx_2^4	$\Sigma x_1x_2^3$	Σx_2^2y	(22y)
					$\Sigma x_1^2x_2^2$	Σx_1x_2y	(12y)

*The experiments were run in random order. The run numbers are referred to later.

The Forward Doolittle for this Example

b_0	b_1	b_2	b_{11}	b_{22}	b_{12}	
10	0	0	3	3	0	816.900
	3	0	0	0	0	49.450
		3	0	0	0	10.132
			2.25	0.75	0	225.375
				2.25	0	224.325
					0.75	−5.239
10	0	0	3	3	0	816.9000
1	0	0	0.3	0.3	0	81.6900
	3	0	0	0	0	49.4500
	1	0	0	0	0	16.4833
		3	0	0	0	10.1320
		1	0	0	0	3.3773
			1.35	−0.15	0	−19.6950
			1	−0.1111	0	−14.5889
				1.3333	0	−22.9333
				1	0	−17.2004
					0.75	−5.2393
					1	−6.9853

Solving for the Coefficients Gives:

$$\begin{aligned}
1(b_{12}) &= 6.9853 \\
1(b_{22}) + 0(b_{12}) &= -17.2004 \\
1(b_{11}) - 0.1111(b_{22}) + 0(b_{12}) &= -14.5889 \\
1(b_2) + 0(b_{11}) + 0(b_{22}) + 0(b_{12}) &= 3.3773 \\
1(b_1) + 0(b_2) + 0(b_{11}) + 0(b_{22}) + 0(b_{12}) &= 16.4833 \\
1(b_0) + 0(b_1) + 0(b_2) + 0.3(b_{11}) + 0.3(b_{22}) + 0(b_{12}) &= 81.6900
\end{aligned}$$

Thus, the fitted equation is

$$\hat{y} = 91.80 + 16.48x_1 + 3.38x_2 - 16.50x_1^2 - 17.20x_2^2 - 6.98x_1x_2$$

Analysis of Variance Table

			ss	*df*	*ms*	
Σy^2			68471.6900	10		
b_0			66732.5610	1		
Linear Terms	b_1	815.0992	849.3180	2		
	b_2	34.2183				
2nd order Terms	$b_{11}\|b_0$	287.3284	718.3884	3	239.4628	$F_{3,7} = 5.59$
	$b_{22}\|b_{11},b_0$	394.4619				$F_{3,3} = 11.09^*$
	b_{12}	36.5981				
Residual			171.4226	4	42.8556	
Lack of Fit			106.6826	1	106.6826	$F_{1,3} = 4.94^\dagger$
Experimental Error			64.7400	3	21.5800	

*Significant at the 5% level. †Non-significant.

We observe that the lack of fit mean square is not significantly different from the experimental error mean square. Two routes of analysis are now open to us.

(1) Accepting the conclusion that both mean squares are estimates of the same variance σ^2, the sums of squares for both can be pooled and divided by their pooled degrees of freedom. This pooled estimate of variance is given by the residual mean square and has four degrees of freedom. The F test indicates that the second order terms in the model are not significant at the 5 percent level.

$$F_{3,4} = \frac{239.4628}{42.8556} = 5.59 \text{ (Non-significant at } \alpha = 5\%)$$

(2) As an alternative analysis, it is not uncommon to continue to use the error mean square for the tests of significance on the model even though the lack of fit term is non-significant. The F test of the mean square for the second order terms now becomes

$$F_{3,3} = \frac{239.4628}{21.5800} = 11.09^*$$

which is significant at the 5 percent level.

To the question "which analysis is correct?" no answer will be given. Pooling to obtain "better" estimates of variance is a highly personal matter with experimental statisticians. One question raised here would be, "Which estimate of error variance is really best?", where the word best requires a weighting of such factors as the number of degrees of freedom, the desire for a conservative (i.e. inflated) estimate, the assumption that the variance is homogeneous over the entire experimental region, etc. Only a person familiar with the data and the circumstances surrounding the data is really in a position to make such a decision.

It is also interesting to note that the F test for second order effects is non-significant in the first instance, significant in the second at the 5 percent level of significance. How would one decide now about the necessity for the second order terms in the model? The important fact to remember here is that one's interpretation of data, whatever its source, should not hinge on a slavish obeisance to a test of significance. The $F_{3,4} = 5.59$ is significant at the 10 percent level. Furthermore, the experimenter's sense of the nature of the response surface, a feeling that should *not* be derived solely from these few data, must also play a role in deciding on the necessity for second order terms. In this example, it is very likely that the second order terms would be declared "real".

Also note that no test of significance is made concerning the individual coefficients making up either the first or second order terms. No such test need be made. The essential point to remember in applying this type of polynomial model fitting is that it is the *order* of the approximating model that counts, not the individual coefficients comprising the model.

For example, suppose we had tested the mean square associated with the b_2 term against the error mean square. Quite obviously we would find a non-significant F ratio and thus conclude that the coefficient b_2 could not be detected as being different from zero. A similar situation exists if we test the single second order term b_{12}. However, even though we cannot detect these estimates as being different from zero, the best estimate of β_2 remains $b_2 = 3.38$, and the best estimate of β_{12} is still $b_{12} = -6.98$. Replacing these estimates, which are unbiased and possess a minimum variance, by zeroes results simply in the construction of a biased mathematical model and should be avoided.

A map of the fitted response surface can now be obtained by substituting, for example, $\hat{y} = 80$ in the fitted model. The resulting equation in x_1 and x_2 will be found to be that of an ellipse in the coordinate system of x_1 and x_2. Figure 18 illustrates the contours for this fitted model.

The location of the center of the fitted system of contours can be obtained by differentiating the fitted second order model with respect to x_1 and x_2, setting these two equations equal to zero, and solving for x_1 and x_2. Thus we get

$$33.00x_1 + 6.98x_2 = 16.48$$

$$6.98x_1 + 34.40x_2 = 3.38$$

The center of the fitted contour system is then $x_1 = 0.50$, $x_2 = 0.01$. In this example the center of the fitted system lies within the experimental region and locates the predicted maximum response. Further experiments should be conducted in this area to confirm this prediction.

In second order model fitting it frequently happens that the center of the fitted contour system will lie far outside the experimental region. In such circumstances it has almost no practical meaning, the "center" point being merely a computational artifact produced by the requirement of curved contour lines in the experimental region. It should always be remembered that the fitted contours (1) *approximate* the unknown response function, (2) provide reasonable approximations only within the experimental region.

Third Order Models

In the above problem, suppose the lack of fit mean square had proved to be significantly different from the experimental error. Would we then proceed to take sufficient additional data to fit the coefficients in the following third order model?

$$y = \beta_0 x_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_{11} x_1^2 + \beta_{22} x_2^2 + \beta_{12} x_1 x_2 + \beta_{111} x_1^3 + \beta_{222} x_2^3 + \beta_{112} x_1^2 x_2 + \beta_{122} x_1 x_2^2 + \varepsilon \qquad (29)$$

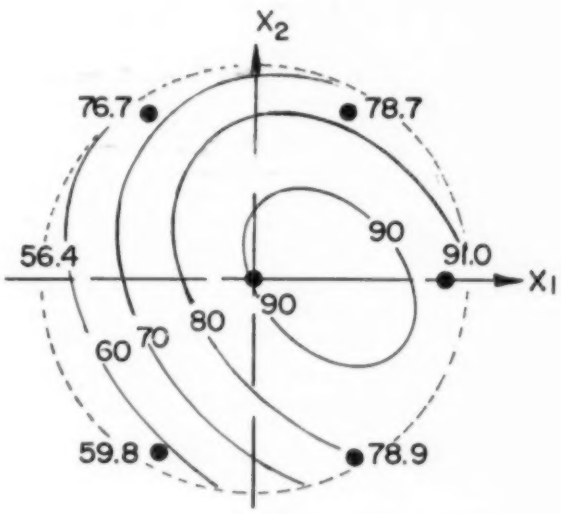

Figure 18 (Center Point Values: 89.4, 90.0, 88.5, 89.3)

From an empirical point of view the usefulness of so involved a fitted function could not be great. Plotting the contours generated by such a model would be a Herculean job, particularly if k, the number of controlled variables, is greater than two. Furthermore there are no easily understood and catalogued forms for these cubic expressions. All second order models can be finally reduced to their "canonical" forms, that is, to ellipses, or hyperbolas or circles, etc. In brief, if a second order model is insufficient to explain the data it is then time to re-appraise the experimental area being studied, the scaling of the controlled variables, (should temperature be fixed in equal arithmetic increments, or in equal increments on the scale formed from the reciprocal of the absolute temperature?) and finally the degree of control over the many physical factors surrounding each experiment. Third order rotatable designs do exist however and can be generated by adding points to existent second order designs.

Formulas for Estimating the Coefficients: 2nd Order Models; Rotatable Designs

So long as a *rotatable* second order design has been used, there is a set of formulas for estimating all the coefficients in the second order model, regardless of the number of controlled variables.

First let

$$c = \frac{N}{\Sigma x_i^2}$$

$$\lambda = \frac{k(n_1+n_2)}{(k+2)n_2} \qquad (30)$$

$$A = \frac{1}{2\lambda[(k+2)\lambda - k]}$$

where

N = total number of observations, including all replicates

k = number of controlled variables

n_1 = number of points at the center of the design

n_2 = total number of points on periphery.

then

$$b_0 = \frac{A}{N}\left[2\lambda^2(k+2)\ (0y) - 2\lambda c \sum_{i=1}^{k}(iiy)\right]$$

$$b_i = \frac{c}{N}\ (iy)$$

$$b_{ii} = \frac{A}{N}\left[c^2[(k+2)\lambda - k](iiy) + c^2(1-\lambda)\sum_{j=1}^{k}(jjy) - 2\lambda c(0y)\right]$$

and

$$b_{ij} = \frac{c^2}{N}\ (ijy) \qquad (31)$$

The terms (0y), (iy), (iiy) and (ijy) are the elements appearing in the extreme right hand column of the Forward Doolittle array, that is

$$(0y) = \Sigma y$$
$$(iy) = \Sigma x_i y$$
$$(iiy) = \Sigma x_i^2 y$$
$$(ijy) = \Sigma x_i x_j y$$

These formulas appear quite cumbersome and for small values of k it would seem best to use the Forward Doolittle approach. Furthermore it must be remembered that these formulas can be used only with data obtained from a second order rotatable design.

Formulas for Constructing the Analysis of Variance Table

The total sum of squares absorbed by all the coefficients in the fitted model equals

$$S_{012} = b_0(0y) + \sum_{i=1}^{k} b_i(iy) + \sum_{i=1}^{k}\sum_{j=1}^{k} b_{ij}(ijy) \qquad (32)$$

with $(k+1)(k+2)/2$ degrees of freedom.

The Residual sum of squares therefore equals

$$S_R = \Sigma y^2 - S_{012} \qquad (33)$$

with $N - (k+1)(k+2)/2$ degrees of freedom.

Provided now that valid replication has occurred, then S_E, the sum of squares for error can be computed, and the lack of fit sum of squares immediately obtained by subtraction, i.e.

$$S_{LF} = S_R - S_E. \qquad (34)$$

The total regression sum of squares S_{012} can also be broken into component parts:

Component	*Sum of Squares*	
Due to b_0	$S_0 = (0y)^2/N$	
Due to 1st order terms	$S_{1.0} = \sum_{i=1}^{k} b_i(iy)$	(35)
Due to 2nd order terms	$S_{2.10} = b_0(0_y) + \sum_{i=1}^{k}\sum_{j=1}^{k} b_{ij}(ijy) - (0y)^2/N$	

The use of the formulas for estimating the coefficients and constructing the analysis of variance for a second order model is illustrated in the following example.

An Example

In studying the effect of two controlled variables upon a response, an experimenter first used a 2^2 factorial design with two center points and obtained the following results (see Fig. 19):

x_1	x_2	y
−1	−1	80.8
1	−1	85.1
−1	1	82.9
1	1	71.9
0	0	82.9
0	0	81.1

A glance at the plot of these data indicates that a planar approximation to the response function is not likely to be adequate. The fitted first order model is, using Equation (25),

$$\hat{y} = 80.8 - 1.7x_1 - 2.8x_2$$

The associated analysis of variance is

	ss	*df*	*ms*	
Σy^2	39262.29	6		
Due to b_0	39155.68	1		
Due to b_1	11.22	1	11.22	$F_{1,1} = 6.9$†
Due to b_2	30.80	1	30.80	$F_{1,1} = 19.0$†
Residual	64.59	3		
Lack of Fit	62.97	2	31.48	$F_{2,1} = 19.4$†
Error $(\frac{\Sigma d^2}{2})$	1.62	1	1.62	

†Non-significant.

On the basis of the tests of significance provided by these data, the experimenter has made no progress whatever since the terms in the model are non-significant. The non-significance of the model, and the lack of fit term, is due primarily to the fact that the estimate of variance $s^2 = 1.62$ is based on only a single degree of freedom, i.e. σ^2 is very poorly estimated. Suppose, however, the experimenter knew from previous work in the same experimental environment that his error variance is, at the most, about $s^2 = 4$. Then, for example, the lack of fit F ratio would be equal about 8. A quick reference to the tables of the F ratio with 2 degrees of freedom in the numerator show that F ratios of this magnitude, with only a moderate number of degrees of freedom in the error mean square (4 or more) are quite rare. On the basis of this additional knowledge concerning the error variance, the experimenter concluded that a first order model could not represent the unknown function and the decision was taken to augment the original design by six additional points (including two in the center), to give the octagonal design array shown in Fig. 20.

x_1	x_2	y
−1	−1	80.8
1	−1	85.1
−1	1	82.9
1	1	71.9
0	0	82.9
0	0	81.1
$\sqrt{2}$	0	81.7
$-\sqrt{2}$	0	82.9
0	$\sqrt{2}$	57.7
0	$-\sqrt{2}$	84.7
0	0	83.8
0	0	80.9

Proceeding now to fit a second order model we have, using the formulas given earlier,

$$N = 12, \quad n_1 = 4, \quad n_2 = 8, \quad k = 2$$

$$c = \frac{3}{2}, \quad \lambda = \frac{3}{4}, \quad A = \frac{2}{3}$$

$$(0y) = \Sigma y = 956.4 \quad (11y) = \Sigma x_1^2 y = 649.9$$

$$(1y) = \Sigma x_1 y = -8.38 \quad (22y) = \Sigma x_2^2 y = 605.5$$

$$(2y) = \Sigma x_2 y = -48.90 \quad (12y) = \Sigma x_1 x_2 y = -15.3$$

Thus the fitted model is

$$\hat{y} = 82.18 - 1.05x_1 - 6.11x_2 + 0.92x_1^2 - 4.63x_2^2 - 1.19x_1x_2$$

The associated analysis of variance is

		ss	df	ms
Crude Sum of Squares		76,880.22	12	
Due to $b_0 = (0y)^2/N = (956.4)^2/12$		76,225.08	1	
Due to 1st order terms: b_1, b_2 $-1.05(-8.38) - 6.11(-43.90)$	$= S_{1\,0}$	307.58	2	
Due to 2nd order terms: b_{11}, b_{22}, b_{12} $82.18(956.4) + 0.92(649.9) - 4.63(605.5) - 1.19(-15.3) - (956.4)^2/12$	$= S_{2\,10}$	184.52	3	
Residual	S_R =	163.04	6	
Lack of Fit	S_{LF} =	157.09	3	52.36
Error	S_E =	5.95	3	1.98

Lack of Fit Test $F_{3,3} = \frac{52.36}{1.98} = 26.44$ (Highly Significant)

In this analysis the lack of fit term is found to be highly significant, an indication that something may be wrong with the postulated model. However, in this example one is also led to wonder whether something might be in error with the observation $y = 57.7$ recorded at the experimental point $(x_1 = 0, x_2 = \sqrt{2})$. Given that the response function is felt to be rather smooth and subject to only gradual changes over the experimental region, this point does appear to be unduly low. It is well to remember that the postulated model may not be the only reason for a significant lack of fit.

Second Order Designs for k = 3

For $k = 3$ controlled variables the second order model contains ten coefficients

$$y = \beta_0 x_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_{11} x_1^2 + \beta_{22} x_2^2 + \beta_{33} x_3^2 + \beta_{12} x_1 x_2 + \beta_{13} x_1 x_3 + \beta_{23} x_2 x_3 + \varepsilon \qquad (36)$$

Rotatable second order designs are provided by the vertices of the icosahedron (12 points) and dodecahedron (20 points) plus a point at the center. However, the most utilitarian design, called "the central composite" design, is formed from the vertices of a cube (8 points) plus the vertices of an octahedron (6 points) with one or more points in the center. The octahedron portion of the design is sometimes called a "star". An illustration of a central composite design, plus the coordinates of the design point, is given in Fig. 21.

Coordinates of a Central Composite Design, k = 3

	x_1	x_2	x_3
2^3 Factorial	−1	−1	−1
	1	−1	−1
	−1	1	−1
	1	1	−1
	−1	−1	1
	1	−1	1
	−1	1	1
	1	1	1
Star Design	$-\alpha$	0	0
	α	0	0
	0	$-\alpha$	0
	0	α	0
	0	0	$-\alpha$
	0	0	α
Center Points	0	0	0
	.	.	.
	.	.	.
	.	.	.
	0	0	0

The first eight points listed in the design matrix are the coordinates of the vertices of a cube, that is the same eight points that form a 2^3 factorial design. The next six points are the vertices of an octahedron, or star, design. To be complete the design requires one or more center points. The value of α, the length of the axis arm of the star design, necessary to make the central composite design for $k = 3$ a rotatable design, is $2^{3/4} = 1.68$, given that the coordinates of the 2^3 factorial are $(\pm 1, \pm 1, \pm 1)$.

Illustrations of the application of second order models for $k = 3$ controlled variables are given in the references (1), (3), (6), (7), and (9).

Second Order Designs for k > 3

The second order model for k controlled variables is

$$y = \beta_0 x_0 + \sum_{i=1}^{k} \beta_i x_i + \sum_{i=1}^{k} \beta_{ii} x_i^2 + \sum_{i<j=1}^{k} \beta_{ij} x_i x_j + \varepsilon \qquad (37)$$

For $k = 4$ controlled variables a rotatable second order design is formed by combining the vertices of a hypercube whose coordinates are given by the 2^4 factorial design with those of the measure polytope with coordinates $(\pm, 2, 0, 0, 0)$, $(0, \pm 2, 0, 0)$, $(0, 0, \pm 2, 0)$ and $(0, 0, 0, \pm 2)$, plus one or more center points. This design is a four dimensional analogue of the central composite design.

A rotatable central composite design for $k = 5$ is formed from the vertices of the 2^5 factorial, the measure polytope with axes arms going from $-\alpha$ to $+\alpha$ where $\alpha = 2^{5/4} = 2.378$, plus one or more center points. In general a k dimensional central composite rotatable design can be formed by combining the 2^k points of the factorial with the 2k points of the measured polytope, plus center points.

However, for $k = 5$ it is unnecessary to run all $2^k + 2k + n$ points $(32 + 10 + n$ center points). A half-replicate of the 2^5 factorial will provide unconfounded estimates of the five first order coefficients, the b_i, and the ten crossproduct coefficients, the b_{ij}. Thus the half-replicate of the 2^5 factorial plus the star design, plus center points provides a second order central composite design. To make the design rotatable the axis arm of the star should equal $2^{(k-1/4)} = 2$.

For $k = 6$ and $k = 7$ rotatable central composite designs are constructed from the 2^k factorial, plus the star design plus center points, or with fewer points from the half-replicate of the 2^k factorial plus the star design plus center points. For $k = 8$ controlled variables a quarter-replicate of the 2^k factorial can be used provided that quarter-fractional factorial is chosen which gives unconfounded first order (b_i) and cross-product (b_{ij}) terms. In general a $(\frac{1}{2})^p$ replicate of the 2^k factorial can always be used provided all the linear and crossproduct coefficients can be separately estimated. For rotatability the axis arm of the star design must be set equal to $\alpha = 2^{(k-p)/4}$ where p is the number of times the 2^k design has been fractioned.

Blocking

A major difficulty in any experimental program requiring a large number of trials is the maintainance of a steady state experimental environment. Experimental results are frequently biased by such factors as time trends, non-homogeneous raw material, differences between shifts of workers, etc. Of course, the biassing effects of such factors can be reduced by ensuring that all the experimental trials are run in a random order. However, the contribution of some factors can be eliminated, or much reduced, by dividing the design program into sub-sets or blocks, each block comprising the experiments run, say, on a given shift, or using a particular batch of raw materials. To reduce the biassing effect of other unidentified factors the experiments are then randomly run within the block.

A further important advantage can be taken of an experimental program which can be run in blocks. Suppose it is the object of the experimenter to determine the nature of some unknown response function. The strategy that is followed by the experimenter is to attempt an approximation of the response function using a first order model. If, for example, a fractional replicate of a 2^k factorial is used for this purpose the experimenter can determine:

1. Whether one or more of the independent variables may be eliminated from consideration (by comparing the relative magnitudes of the fitted coefficients in the first order model), or whether the intervals between the settings of the variables should be extended or reduced.
2. Whether a planar model is adequate to represent the response by noting the evidence of lack of fit either from the estimates of the b_{ij} terms or from the evidence of curvature provided by the center points.
3. Granting that a planar model is adequate the decision can be taken to move to a region of higher response using a path of steepest ascent.

If a non-planar response is observed the experimental design should then be augmented to permit the estimation of all of the coefficients in a second order model. This is quickly accomplished by adding whatever additional fractions of the 2^k factorial are necessary to obtain unconfounded estimates of the b_{ij} and the b_i terms; and finally by adding an additional block of points for estimating the b_{ii} terms. These additional blocks of experiments would thus be run after decisions have been taken from one or more of the preliminary blocks. *Thus the experimental program would progress sequentially, each group or block of experiments being separately appraised to provide information for the next step.*

A danger to this sequential approach lies in the possibility that some external change in the experimental environment may generally raise or lower the average level of the response from one block of experiments to another. This danger is eliminated if the second order designs can be blocked so that the estimates of the linear, crossproduct and quadratic coefficients are not influenced by these block to block differences.

Rules have been determined which permit most second order rotatable designs to be blocked. The most important practical restriction to blocking the designs is that each block must in itself form a rotatable first order design. Fortunately, the 2^k factorial, the fractional factorials, and the star designs are by themselves rotatable first order designs. However, in order to make the estimated coefficients in the second order model orthogonal (completely independent) of any differences contributed by block effects, care must be taken properly to weight the numbers of points at the center of each block. Descriptions of the methods for blocking second order designs appear in references (5) and (9).

As an example of the use of blocking, suppose all the odd numbered runs in the worked example illustrating the use of the Hexagon design had been performed first. It will be observed that these runs form an equilateral triangle and hence this block of runs is a rotatable first order design. Fitting the first order model gives:

$$y = \beta_0 x_0 + \beta_1 x_1 + \beta_2 x_2 + \varepsilon$$

Vector of Obs.	Matrix of Ind. Var.		
	x_0	x_1	x_2
96.0	1	1.000	0
76.7	1	−0.500	0.866
64.8	1	−0.500	−0.866
97.4	1	0	0
93.0	1	0	0

Forward Doolittle

b_0	b_1	b_2	
N	Σx_1	Σx_2	Σy
	Σx_1^2	$\Sigma x_1 x_2$	$\Sigma x_1 y$
		Σx_2^2	$\Sigma x_2 y$
5	0	0	427.900
	1.5	0	25.250
		1.5	10.305

Solving gives

$$\hat{y} = 85.58 + 16.83x_1 + 6.90x_2$$

The Analysis of Variance Table is

	ss	*df*	
Σy^2 =	37433.69	5	
b_0	36551.25	1	
b_1	431.71	1	
b_2	70.80	1	
Residual	379.93	2	
Lack of Fit	370.25	1	$F_{1,1} = 38.24$ $F_{1,1}$ at 10% = 39.86
Error	9.68	1	

(Tests of significance in this example will hardly be meaningful, since the error variance is based on only one degree of freedom.) On the basis of this evidence let us suppose that the experimenter now wishes to augment the equilateral triangle design so as to provide enough information for estimating all the coefficients in a second order model in this experimental region. Imagine then that a second equilateral triangle (the even numbered runs) with two center points is added to the first, this second block of experiments forming with the first block of experiments, a hexagon design. However, let us suppose that the second block of experiments give observation everywhere depressed by 10 percent, i.e. observation number two now equals 78.7 − 10.0 = 68.7 percent. The new vector of observations would then be

Vector of Obs.	Matrix of Ind. Var.							
y (%)	x_0	x_1	x_2	x_1^2	x_2^2	x_1x_2	β_1	β_2
96.0	1	1.0	0	1.00	0	0	1	0
68.7	1	0.5	0.866	0.25	0.75	0.433	0	1
76.7	1	−0.5	0.866	0.25	0.75	−0.433	1	0
44.6	1	−1.0	0	1.00	0.	0	0	1
64.8	1	−0.5	−0.866	0.25	0.75	0.433	1	0
68.9	1	0.5	−0.866	0.25	0.75	−0.433	0	1
97.4	1	0	0	0	0	0	1	0
80.5	1	0	0	0	0	0	0	1
93.0	1	0	0	0	0	0	1	0
76.3	1	0	0	0	0	0	0	1

Ignoring for the moment the Block I and Block II column vectors in the matrix of independent variables, the Forward Doolittle solution for the coefficients becomes

b_0	b_1	b_2	b_{11}	b_{22}	b_{12}	
10	0	0	3	3	0	766.9000
	3	0	0	0	0	49.4500
		3	0	0	0	10.1320
			2.25	0.75	0	210.3750
				2.25	0	209.3250
					0.75	−5.3290

The coefficients b_1, b_2 and b_{12} can be determined by sight. All the off diagonal elements associated with these terms are zeros and hence we know directly that, for example, $b_2 = 10.1320/3 = 3.3773$ and furthermore that the sum of squares attached to this estimate is given by (3.3773) (10.1320) = 34.2188. This reduces the elements to be handled directly by the Forward Doolittle technique to

b_0	b_{11}	b_{22}	
10	3	3	766.9000
	2.25	0.75	210.3750
		2.25	209.3250
10	3	3	766.9000
1	0.3	0.3	76.6900
	1.35	−0.15	−19.6950
	1	−0.1111	−14.5889
		1.3333	−22.9333
		1	−17.2004

Solving for the coefficients:

$$1(b_{22}) = -17.2004;\ b_{22} = -17.2004$$
$$1(b_{11}) - 0.1111(b_{22}) = -14.5889;\ b_{11} = -16.5000$$
$$1(b_0) + 0.3(b_{11}) + 0.3(b_{22}) = 76.6900;\ b_0 = 76.4799$$

Thus the fitted equation is

$$\hat{y} = 76.48 + 16.48x_1 + 3.38x_2 - 16.50x_1^2 - 17.20x_2^2 - 6.98x_1x_2$$

With the exception of the b_0 coefficient, *the fitted model is identical to the earlier one.* The shape of the fitted contour surface will thus remain unchanged despite the fact that Block II depressed all yields.

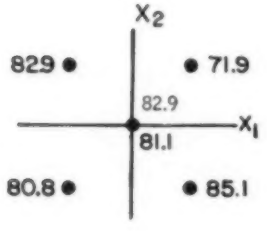

Figure 19

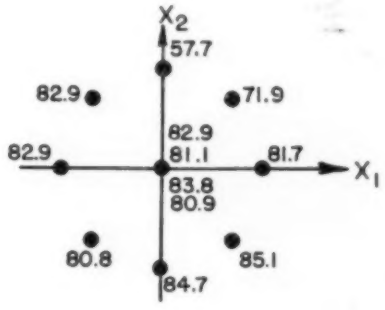

Figure 20

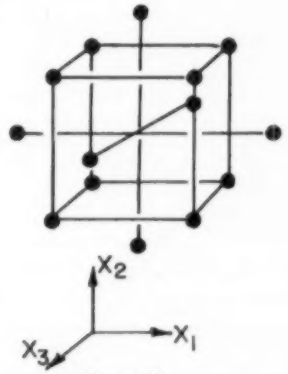

Figure 21

Analysis of Variance Table

	ss	*df*
Σy^2	61191.6900	10
Due to Blocks	790.3210	1
b_0	58813.5610	1
Linear Terms	849.3180	2
2nd Order	718.3884	3
Residual	20.1016	3
Lack of Fit	1.6016	1
Error	18.5000	2

The block sum of squares is determined as in regular Analysis of Variance. Thus we take

$$\sum_{1}^{2} \frac{(B_i)^2}{n_i} - \frac{(T)^2}{N}$$

where

B_i = Total for Block i

n_i = Number of obs. in Block i

T = Grand Total of obs. = Σy

N = Total number of obs.

or

$$\frac{(427.9)^2}{5} + \frac{(339.0)^2}{5} - \frac{(766.9)^2}{10} = 790.3210 \quad (38)$$

The error sum of squares must now be obtained from within each block and then pooled. Since there are two repeated observations in each block, the error sum of squares is given by $\frac{\Sigma d^2}{2}$ or $\frac{(4.4)^2 + (4.2)^2}{2} = 18.5000$ with 2 degrees of freedom. We observe that the lack of fit term is non-significant, that the second order terms are significant, and that the contribution of the block effects is significant. However, the differences between the blocks did not obscure the shape of the fitted contours since all the coefficients associated with x_1, x_2, x_1^2, x_2^2 and x_1x_2 have remained unchanged.

So long as the points comprising a rotatable design can be broken into blocks all with an equal number of points, and each block by itself forming a first order rotatable design, then the number of points required at the center of each block remain equal, and the full second order design remains rotatable. Thus, the octagon design can be broken into two blocks, each block having four peripheral points plus two center points. The center point is replicated within each block to provide an estimate of error.

However, it is not always possible to split up a second order design into blocks all with equal number of points, and have each block be a rotatable first order design. For example, the central composite design for $k = 3$ controlled variables can be broken down into three rotatable first order designs: two provided by the two half-replicates of the 2^3 factorial each with four peripheral points, and the third block by the star design with six peripheral points. It is now impossible to guarantee rotatability *and* orthogonal blocking. However, if the axis arm of the star design is changed from 1.682 units (the distance for rotatability) to 1.633 units, and two center points are placed in each block, then orthogonal blocking is obtained. The design is only slightly non-rotatable, the change from 1.682 to 1.633 being barely noticeable.

The central composite design for k=4 controlled variables can be orthogonally blocked and remain rotatable. Two blocks are formed from half-replicates of the 2^4 factorial (each has eight peripheral points) and from the star design (also with eight peripheral points). Here the axis arm for rotatability plus orthogonality is $\alpha = 2.000$, each block containing at least two center points.

The table given below lists the number of points required for rotatable or near-rotatable, or orthogonally blocked, central composite designs. This table is abridged from reference (5). Other tables of rotatable designs appear in references (5) and (13).

k	2	3	4	5	5(½ rep.)
n_c: Number of points in cube	4	8	16	32	16
Number of blocks in cube	1	2	2	4	1
Number of points in block from cube	4	4	8	8	16
Number of added center points	3	2	2	2	6
Total number of points in block	7	6	10	10	22
Axial block					
n_a: Number of axial points	4	6	8	10	10
Number of added points	3	2	2	4	1
Total number of points in block	7	8	10	14	11
Grand total of points in the design	14	20	30	54	33
Value of α for orthogonal blocking	1.4142	1.6330	2.0000	2.3664	2.0000
Value of α for rotatability	1.4142	1.6818	2.0000	2.3784	2.0000

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uses of total quality control in

Top Management Decision Making*

JAMES F. BOURQUIN

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This article will treat the role quality activities can play in top management decision making. By eliminating expertese in statistical quality control, we can feel free to discuss this area from a management viewpoint, paying particular attention to the ways in which quality control can effectively help decision making at the highest management levels. I am sure this is a basic issue in all industries. It surely is one of our chief day-to-day concerns at Whirlpool. Of course, the ways in which we, as quality control people, can make a contribution to management must necessarily vary with company size, type of product, and market served. To better understand our approach and to isolate specific steps in our program which might be useful in applications in other companies, the subject will be developed under four general headings:

1. *Whirlpool's recent historical background, product mix, methods of distribution, and market served.*
2. *The nature of problems created by our type of product and company structure.*
3. *The basic framework of policy as developed for quality functions that contribute to management guidance.*
4. *Specific examples in the key areas of design evaluation, process inspection and product control, quality audits, and field service experience.*

General Background

Whirlpool Corporation, as constituted today, is vastly different from the Upton Machine Company of St. Joseph, Michigan which first supplied a washing machine to Sears, Roebuck and Company in 1916. Although the original company became the sole supplier of home laundry equipment to Sears in 1922, it was in the late 1940's before products marketed through a dealer and distributor organization under the Whirlpool brand name were promoted on a national basis. The dual distribution marketing plan, providing two competing lines from the same facilities, combined with the post-war boom and quality-oriented engineering to give impetus to steady growth. Additional facilities were rapidly acquired after 1950: a plant and warehouse in LaPorte, Indiana, in 1951; others at Clyde, Ohio, in 1952 and '53; and another at Marion, Ohio, in 1955. Employment rose from 1500 in 1948 to a total of 6000 in mid-1955. The present company is actually the product of a merger in September, 1955 of the "old" Whirlpool Corporation, the Seeger Refrigerator Company, and the range and air conditioning divisions of RCA. There are now nine manufacturing plants, in six divisions, with approximately 13,800 employees.

*Presented to the Winnebago section of the American Society for Quality Control.

It became apparent in 1950 that there was a new trend in appliance distribution. It was obvious that the manufacturer who could provide a full line had significant advantages over companies building a single set of family products. The merger in 1955 stemmed from the needs indicated by these trends. The new Whirlpool Corporation brought together manufacturers of home laundry appliances, refrigeration products, and kitchen ranges. Intensive internal engineering research had developed many consumer products which could be released for manufacture in the varied facilities which became available. By early 1958, this had resulted in a product mix of: automatic washers, dryers, ironers, combination washer-dryers, wringer washers, refrigerators, freezers, food waste disposers, ice cube makers, free-standing electric and gas ranges, built-in gas and electric ranges and ovens, room and central air conditioning, and vacuum cleaners.

Another major long range effort was consummated last January with the acquisition of the Servel facilities which had been utilized in the manufacture of its gas refrigerator and an automatic ice maker. This move was made to meet the needs of the gas utility companies which found themselves without a supplier of gas refrigerators after Servel ceased manufacturing operations early in 1957. The new relationship greatly broadens the potential marketing area for promotion and sale of our entire gas appliance line.

Inherent Problems

It is obvious that this type of progress has not been without its cost. Rapid introduction of new products in response to consumer needs, and violent schedule fluctuations in quick response to demands of the consumer market, has made increasingly greater demands on the quality control staff. Nation-wide distribution with varying climatic and use conditions for the same product has called for increasing sensitivity to field service information. Transfers of operations between plants, formation and training of new management groups, and the concepts of decentralized, autonomous divisions all have highlighted the role which the quality organization has had to play.

Basic Policies

What overall framework of policy is essential to implement quality functions within autonomous divisions where there are diverse product problems in varying facilities? A few general principles set the stage for the quality activity at both division and corporate levels.

There are three fundamental concepts which we have found necessary:

1. *Quality is a line responsibility of the operating organization.* This cannot be dodged or passed off on a vendor, customer, or as a sales function. Divisional quality directors must strive for the total quality of the product, including design, process and vendor surveillance. At Whirlpool, our quality control managers have both the responsibility and the authority to stop any operation which is running outside quality limits. On our assembly lines, it is not unusual for an inspector to issue the order "stop the line", with an explicit understanding that only when positive steps have been taken by production supervision can the line be started again.
2. *Quality is a management function* of equal stature with engineering, purchasing or manufacturing. The quality organization reports directly to top management at the same divisional staff level as a chief engineer, purchasing director or manufacturing manager. In both theory and practice, the quality control groups are independent of the production line organization and are free of pressure of meeting schedules. In other words, quality considerations are paramount and are placed ahead of sales schedules and short-term demands.
3. *Quality is common understanding*, a mutual appreciation that our survival depends on supplying products which are competitive in price and design and are of superior quality.

To implement these policies, in keeping with the other dynamic forces in our company, we have found it necessary to explore every means of making positive contributions to management direction. This necessity has plunged us into use of the "total quality" concept. Of course, the principle of this total quality idea—and its fundamental difference from other more limited viewpoints—is the realization that in order to be really effective, control must start with the design of the product and end only when the product has been placed in the hands of a customer who is so pleased she will return to us in the future.

We are all familiar with this basic premise and, admittedly, the catch phrase "total quality control" has become greatly overworked in recent years, in the same manner that statistical quality control became so fashionable shortly after World War II. However, to us at Whirlpool, total quality has become very real—sometimes rather painfully so. This viewpoint has made it possible for us to focus quality efforts on several basic areas.

Key Quality Areas

We feel that the scope of our overall contribution can be broken down into four general classifications:

1. **New design evaluation.** This deals with such activities as product engineering and manufacturing engineering. A close relationship is essential between these functions and the function of the quality director in planning controls for new or modified products prior to the start of production, and careful evaluation of new products or features through large-scale field testing before volume production is begun.
2. **Control of processed and purchased material.** This deals with work within our manufacturing facilities including shop operations, inspection and testing functions, and the functions of purchasing and receiving inspection.
3. **Quality Audits.** Daily appraisals using customer acceptance laboratory testing as a surveillance medium in measuring the success of our own in-plant quality efforts has provided a valuable means of measuring trends in the outgoing quality level of our product and has provided a quick method of forcing defect problems back into the processing source.
4. **Field Service.** A unique means has been developed to identify from service call trends the longer term product defects, either from manufacturing or engineering, which would not normally be apparent until a later date.

Design Evaluation

An example of design evaluation occurred recently at one of our divisions. A major product improvement involving several basic changes will soon be introduced in home refrigeration. With this major change in the product and the various new features which are made possible, it was necessary to add many special parts, including a timer, two solenoids, special switches, additional light bulbs and several fans. An important session in the design evaluation was a meeting between the divisional quality director and the chief engineer to consider each component which represented an addition above and beyond equipment already being produced. Based on a thorough analysis, using service data of similar components on other products in our line which are built or used by other divisions, it was possible to *estimate* item by item our *expected field service problem* or overall quality liability from each added component, assuming future experience would follow the current pattern.

This type of analysis serves several purposes. It permits the sales and service departments to assess the quality implications of a new product, such as the need for specific training of service personnel, and it provides a basis for estimating in-warranty and free-service costs. The engineer is able to rapidly assess the sensitivity of his product to the addition of new gadgets, and the quality director working with purchasing has a good planning basis for revising or tightening his Acceptance Quality Levels in receiving inspection on many purchased components. The field liability we face, and the higher quality standards we require, are thus made clear to top operating and sales management, long before the actual production date.

Thorough *field testing of new product or feature developments* is also a most significant factor in the design evaluation. We firmly believe that our equipment must be tested in actual use by the consumer before release for production. It is not uncommon for production schedules to be revised or postponed until proper field evaluation has been made. Through experience, we have found that laboratory or engineering testing alone is not entirely adequate as an estimate of what we can expect from a product in the field.

Process and Purchased Part Controls

Effective in-plant use of quality control has made our management decisions easier in the area of *capital expenditures.* A recent case developed in one of our porcelain facilities from a proposal for the purchase of a special, new type of equipment designed to more efficiently apply the outer white coat of enamel to sheet metal parts. An investment of over $100,000 plus installation and start-up costs showed a possible amortization in less than two years from projected reductions in material usage. Quality control was at that time actively participating with industrial engineering in process studies towards reduction of material usage costs. This involved careful inspection counts of approved ware,

IBM tabulation of total footages run, accurate measures of weekly material usage, establishment of additional inspection control points, and, finally, a regular statistical evaluation of material usages. The program also required re-education of all levels of supervision and identification in greater detail as to causes for rejection. Personnel were re-trained and necessary corrective measures applied, resulting within ten weeks in material usages with existing equipment less than had been promised for the new expensive installation. An obvious decision was that despite certain desirable features, the proposed purchase could not be amortized rapidly enough to justify the investment.

A similar situation occurred in 1956 on a somewhat larger scale. As you are aware, there has been a demand for porcelain enamel finishes on home appliances. All-porcelain machines, even though they are expensive, have taken the fancy of many American housewives because they represent top quality. From a management standpoint, one of the problems thus created is the capital investment necessary to provide adequate porcelain facilities. In rough figures, a modern automated plant of this type might require in excess of $3,000,000. Our management was faced with the situation of having two divisions in Ohio which produced products with a high percentage of porcelain finish, and a processing facility at only one of the plants. It was questionable whether the one existing first-class porcelain facility could supply both operations. However, statistical quality control had never been applied in the operation of this recently acquired division so we decided to run an experiment and go all out and apply these methods to control of operations at the plant, at the same time keeping an accurate measurement of quality levels before and after the installation. In four months, the percentage of rejects at the newly established control points had dropped approximately 29 percent. Whereas, the plant formerly had difficulty in meeting a minimum schedule, after some facility adjustment and training of new personnel and with careful controls on quality, it was able to produce 130 percent more tops per day.

When the increased capacity was related to possible plant and equipment investment, top management decided that capital expenditures could be postponed. In fact, the same facility still serves the two divisions without hardship.

The quality director has a vital part to play in judgments of the work force, estimates of changes necessary to handle schedule fluctuations, and evaluations of supervisory capabilities. For example, Fig. 1 shows the weekly total of assembly defects found on our combination washer-dryer line at the St. Joe Division for the last half of 1957 and the first part of this year. It illustrates how statistical quality control pointed out a problem, helped analyze some of the reasons for the problem, and showed progress towards elimination. As you can see from the chart, we were rapidly dropping down into the "smooth operation range" until October 1, 1957. The report issued during that week showed an upturn, but of no great magnitude. Normal attention was given to the operation, watching to see if it was just a peak or a new trend. The following week, however, the defect curve made a very decided upturn for the worse, putting our defect level back to where it had been the previous September.

This was brought to the full attention of management by the quality director and the reason was determined to be one of worker attitude caused by a layoff on October 1st. Continuation of the high defect rate in-

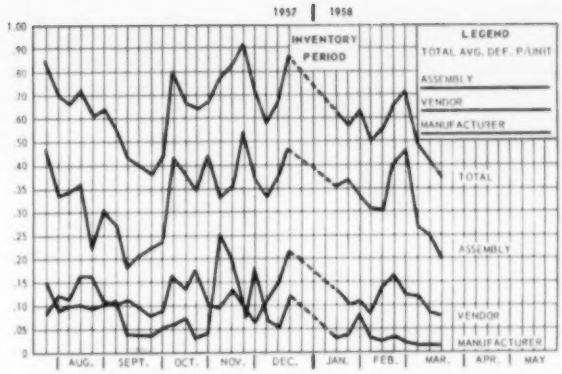


Figure 1—Combination Washer-Dryer Responsibility Analysis of Weekly Average Defects per unit at Final Assembly

dicated that their attitude was being reflected in poor workmanship on the assembly line, not just a training problem due to bumping. This called for intensive work with and by supervision and the addition of more inspection to maintain the proper outgoing quality level. The defects were analyzed as to source and identified as those attributable just to assembly, those originating by processing work done in our plant, and incoming vendor material. The sensitivity of this type of statistical control to employee attitudes is further shown with schedule increases in February which rapidly resulted in an *improvement* in quality. We are confident this is also an indication that the employees better understand, in the present economy, the advantage of having a good job and the necessity of doing good work.

Process capability studies of specific parts can play a major role *in obtaining the proper engineering decisions*. As we have all experienced, engineers are generally the type of individuals by experience and training that have to be dealt with using facts. Conversation around and about a problem seldom seems to satisfy them. An interesting illustration of this approach was recently made at our Marion Division.

A careful study was made in an effort to reduce noise and bearing failure problems in assembly of the fan bearing and fan shaft used in both gas and electric dryers. Many careful measurements established that the bearing manufacturers' tolerances coincided with our print tolerances and that the mean size was fairly well centered about the mean value of the specification. This

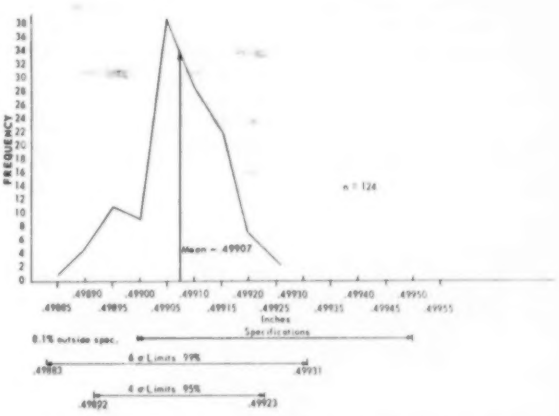


Figure 2—Machine Capability Study on Purchased Dryer Fan Shaft Diameters

was not exactly the case for the purchased fan shafts. As illustrated in Fig. 2, precise measurements indicated two problems. First, the mean value of the shaft diameter did not correspond with the mean of the existing specification. This showed that the process must be shifted slightly. Secondly, the specification value itself should be altered by changing the mean shaft diameter from 0.4995 to 0.5018. The revision would throw shaft bearing clearances between 0 and 0.001, a more desirable condition than the present clearances of 0.0015 to 0.0030. When the processes are in control and the shafts selected at random for assembly, less than one percent of the parts require selected fitting as compared to the original situation where an excess of eight percent were out of specification and on the low side contributing to loose fits, noise, and bearing failures. The rather limited illustration is used to point up the possibilities for using factual presentations of control data to establish the feasibility of doing a better quality job with changes in processing, or engineering specifications.

Quality Audits

We have found that there is a vital management need for a current measuring stick of the outgoing quality level by product and by division, and some overall estimate of quality trends in the corporation. This is being done by what we call our customer acceptance laboratories. These are a separate function, not part of the regular inspection organization, reporting directly to the quality manager at each division.

A small sample is pulled at random from units which are either already packaged or which have received the final inspection stamp of approval. The appliances are set up, cycled, and carefully checked for all defects which would be apparent at time of installation or during very early use. Since the result of these independent audits on product actually being shipped go to divisional management on a daily basis, and to the corporate operating vice president on a weekly basis, we have found that any problems discovered are backed very rapidly into the processing source for immediate correction. Figure 3 is a typical weekly report from our air conditioning operation at Evansville and shows the standard form used by all divisions. The example identifies an interesting and highly provocative situation which developed in early December. Start up of a very expensive new high humidity test facility for the customer acceptance laboratory on air conditioning resulted in a striking rise in the number of defects reported. As you can easily believe, rapid management action followed, with improvements immediately being introduced into processing and assembly. The second peak which occurred

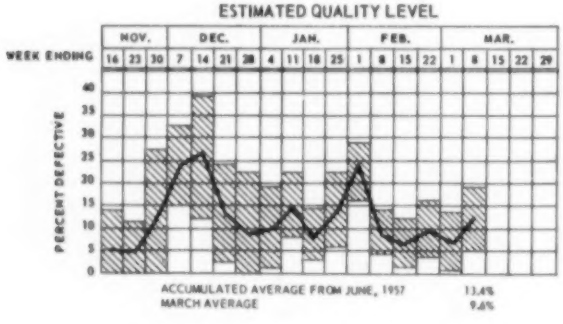


Figure 3—Consumer Acceptance Laboratory Test Report for Room Air Conditioners

at a later date shows the start up on a new model, resulting in rapid correction of certain problems.

We feel that the trend of the results from the actual sample taken is more significant in these tests than the shaded area of 90 percent probability, which is a function of the size of the sample taken.

Use of Field Service Information

Shortly after the war, another vital quality technique was established in our company. This control is a measurement of the number of service calls to customer homes as a ratio of the number of sales.

Obviously, it was not necessary from a statistical standpoint to attempt a 100 percent check on field performance, so a number of key outlets were designated as TEST STORES. Annual sales volume from these stores represents from 7-10 percent of the total retail volume, and are scattered throughout the country to give varying conditions typical of all the major differences in climate or operating conditions. In each of these stores, servicemen keep a complete and accurate record of the reasons for every call that comes in from a customer for each of our products. These calls are totalled monthly for all assignable problems. Service calls traced back to either installation or customer instruction covering our equipment are listed as store responsibility. All other causes are listed as Whirlpool responsibility and are summarized by component and for the entire assembly. Since these test store locations also report total sales for each of our products at the end of each month, it is possible to quickly translate these findings into quality control trend charts.

A typical chart (see Fig. 4) shows results from late '56 through mid '58 on refrigerators. A reading of 100 would mean that we are having service calls on an annual basis of one per unit. Each month our top management people receive the supporting statistical data as well as small trend graphs by component. This chart is interesting as it shows the marked seasonal trend in refrigeration problems. In the warm summer months, we had about 8/10 of a service call per unit sold on an annual basis, with a considerable drop off during winter months.

For products and components which have a background of experience, we also show the previous year's record for reference purposes, as shown on Fig. 5, a chart of the electric dryer. As you can guess, any rise in the trend line of service calls on a component serves as a potent danger signal to each member of our management team. Several years ago the trend line for switches rose rapidly over several months. Additional checking procedures were set up in incoming receiving inspection departments in accordance with our acceptance sampling tables. Quality control charts were established and a correlation of defective percentages at time of receipt was made with the indicated field experience. An acceptable quality level with a sound basis of fact could then be set up, and followed with full understanding, both by our plants and the vendor. Figure 6, a report on switches, also aptly illustrates a situation where the upward trend was allowed to continue too long before design improvements and tightened controls were established.

When the timer trends shown in Fig. 7 became apparent, our vendors were fully advised of our findings and required to set up quality controls in their own facilities which would tie in with our acceptance sampling in receiving, since we had established that the percentage of defective merchandise received at our

plants closely paralleled the percentage of defective parts in the field. The improvement in succeeding months is readily apparent.

Sensitivity to field trends has helped receiving inspection. It has been possible through a careful program of acceptance sampling studies, to work out certification agreements with certain of our suppliers. These agreements provide that the necessary statistical quality controls will be established by the supplier and that each lot of parts they send us will be certified to be within agreed upon limits of acceptability. We are then able to send parts directly to assembly without incurring large inspection costs. From a management standpoint, this program of acceptance sampling and

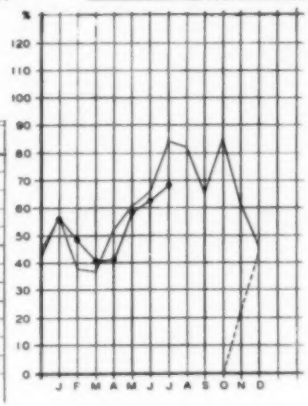
REFRIGERATORS

QUALITY CONTROL REPORT

1956 ------
1957 ——
1958 •—•—•

% OF SERVICE CALLS TO SALES

	1956	1957	1958
JAN.		57.0	56.8
FEB.		37.8	48.3
MAR.		38.7	40.6
APR.		52.1	41.0
MAY		80.3	58.3
JUNE		65.9	82.8
JULY		83.9	88.4
AUG.		82.0	
SEPT.		65.7	
OCT.		84.6	
NOV.	22.3	81.8	
DEC.	43.4	45.8	



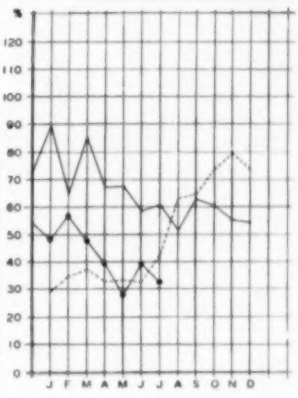
ELECTRIC DRYERS

QUALITY CONTROL REPORT

1956 ------
1957 ——
1958 •—•—•

% OF SERVICE CALLS TO SALES

	1956	1957	1958
JAN.	29.0	89.5	48.2
FEB.	34.7	85.0	57.0
MAR.	37.2	85.4	47.9
APR.	32.7	87.2	38.4
MAY	33.0	87.8	28.0
JUNE	32.5	58.7	39.2
JULY	42.3	60.9	32.5
AUG.	63.0	51.8	
SEPT.	64.6	82.9	
OCT.	73.8	80.2	
NOV.	70.8	55.4	
DEC.	73.3	54.1	



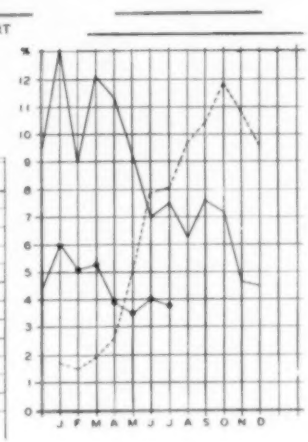
AUTOMATIC WASHERS

QUALITY CONTROL REPORT
COMPONENT- SWITCHES

1956 ------
1957 ——
1958 •—•—•

% OF SERVICE CALLS TO SALES

	1956	1957	1958
JAN.	1.7	13.0	6.0
FEB.	1.5	9.0	5.1
MAR.	1.9	12.1	5.3
APR.	2.6	11.3	3.9
MAY	5.0	9.3	3.5
JUNE	7.8	7.0	4.0
JULY	8.1	7.5	3.8
AUG.	9.7	6.3	
SEPT.	10.4	7.6	
OCT.	11.8	7.2	
NOV.	10.6	4.7	
DEC.	9.6	4.5	



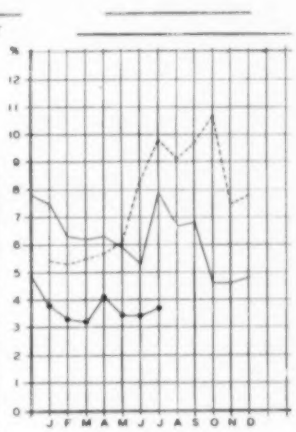
AUTOMATIC WASHERS

QUALITY CONTROL REPORT
COMPONENT TIMERS

1956 ------
1957 ——
1958 •—•—•

% OF SERVICE CALLS TO SALES

	1956	1957	1958
JAN.	5.4	7.5	3.6
FEB.	5.3	6.3	3.3
MAR.	5.5	6.2	3.2
APR.	5.7	6.3	4.1
MAY	6.1	5.9	3.4
JUNE	6.3	5.3	3.4
JULY	9.8	7.9	3.7
AUG.	9.1	6.7	
SEPT.	9.7	6.0	
OCT.	10.7	4.6	
NOV.	7.5	4.6	
DEC.	7.8	4.6	



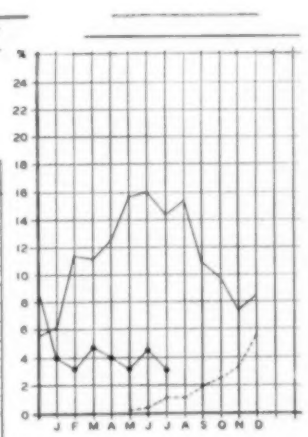
AUTOMATIC WASHERS

QUALITY CONTROL REPORT
COMPONENT UNI-DIRECTIONAL PUMP

1956 ------
1957 ——
1958 •—•—•

% OF SERVICE CALLS TO SALES

	1956	1957	1958
JAN.		6.1	4.0
FEB.		11.4	3.2
MAR.		11.2	4.7
APR.		12.4	4.0
MAY	.2	15.7	3.2
JUNE	.4	16.0	4.5
JULY	1.2	14.3	3.1
AUG.	1.2	15.3	
SEPT.	1.9	10.9	
OCT.	2.5	9.8	
NOV.	3.3	7.4	
DEC.	5.6	8.4	



Figures 4-8—Service Calls vs. Unit Sales as Reported by Test Stores

vendor certification has been helpful in choosing good sources of supply and maintaining fine relationships with our vendors.

Early last year, a trend developed in our automatic washer pump assembly as shown in Fig. 8. An analysis was presented to the quality control department based on specific data from the field. The quality manager and service people were able, using this data, to establish a mutual understanding with engineering as to the product improvement action to be taken. For example, in January '57 the housing material was changed from plastic to die cast and a 100 percent operation was added to drain the pump housing before shipment and eliminate danger of freeze cracks. A revised impeller was specified and an improved seal added. The weight of product in the field shows in the rising trend line for several months; however, the effect of the improvements are apparent starting in mid '57.

We feel that this type of quality analysis is a highly valuable management tool both in showing our long-term results of engineering design problems and manufacturing errors. The index is sufficiently sensitive that a percentage of any type defect shows up rather quickly in the trend.

Summary

Cases have been shown of how management direction can be helped through effective use of quality control in the four major aspects of our work. These examples come from all the major portions of the total quality picture starting with design evaluations through processed and purchased material controls, quality audits and the sources of vital information through field service reporting.

In outlining quality control contributions to management, situations have been used from Whirlpool activities. However, it is reasonable to assume that similar steps are being performed in some form by nearly all industry. Wherever manufacturing operations are carried out, an ever increasing amount of attention is being given to quality. This is accompanied by steadily mounting pressures for better techniques, education, and controls. The growth beyond the level of merely pinpointing defects through statistical sampling methods without significant plans and long-range objectives, to a new position of vital force in management direction, is a solid indicator of the quality function's rising stature in today's industry.

Management's Corner

J. M. JURAN, Editor

A Note on Economics of Quality

J. M. JURAN*

In the last few years this department encountered an opportunity to study a cause and effect relationship between product quality and resultant sale of the product.

Data on which such studies can be based are rare indeed. In this instance, the data were available due to the fortuitous presence, within the same company, of quality and sales data on a wide list of competing products. (The company in which these studies were made is a leader in its field, and is alert to make use of factual data to improve its operations.)

The products in question were all consumer type goods. These goods exhibit a variety of qualities, including certain sensory qualities which are believed by the people in the industry to be critical in achieving sales.

The data have been reduced to a single correlation (Fig. 1) reflecting quality as the cause, or independent variable, (on the X axis) and sales as the effect, or dependent variable, (on the Y axis). A word of explanation is in order on the construction of Fig. 1.

The company conducts extensive "consumer quality preference" tests.† These tests consist essentially of submission, to consumers, of paired products A and B. The consumers use these products and then express a quality preference, if any, for A or B. For example, the company's product A competes* with product B made by a competitor. Samples of A and B are submitted to 500 consumers, who then express quality preference as follows:

Prefer A	240
Prefer B	160
No preference	100

In Fig. 1, the consumer quality preference for product A would be regarded as 60 percent, i.e., 240 is 60 percent of the 400 consumers making a choice.

*Consulting Management Engineer, New York, N.Y.

†The tests are well designed statistically to minimize bias and other experimental errors.

*"Competing products" in this study were competing in the dictionary meaning of the word. The competing products served the same functional use, were sold in the same sales channels, to the same market, and at essentially identical prices.

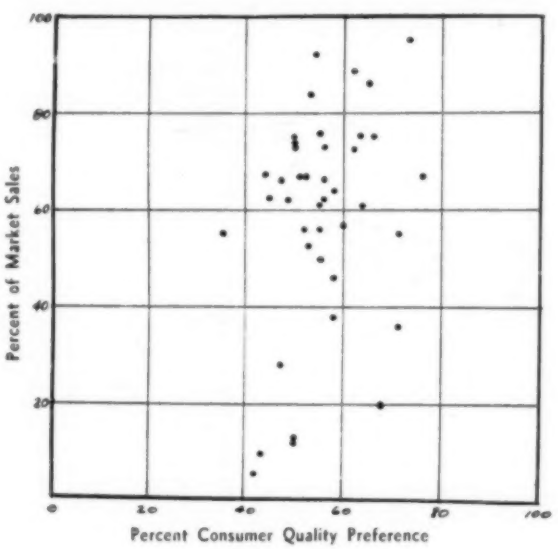


Figure 1

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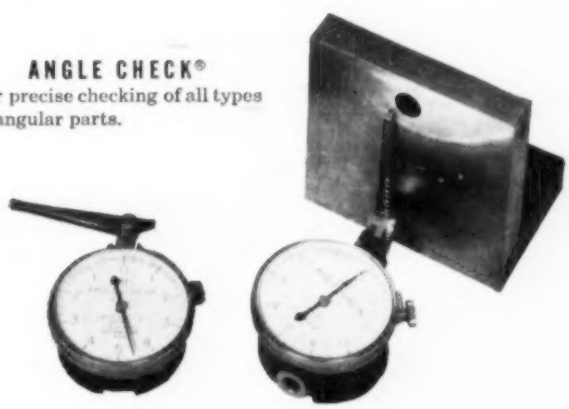

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(You are invited to read this issue's *From the President's Desk*, page 4, which contains additional information about Technometrics.)

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The company also secures extensive information on the actual sale of its products (and those of competitors) at the retail level. These data are available in the form of "percent of market sales." For example, the company's product A competes with products B, C and D sold by the competitor companies.

The resulting "percent of market sales" are:

Product	*Percent of Market Sales*
A	60
B	20
C	15
D	5

In Fig. 1 only that part of the market commanded by A and B has been considered. A has 75 percent of the total of A + B, and hence is in Fig. 1 regarded as having 75 percent of market sales.

In this way, the information available on products A vs. B has been reduced to two preference percentages:

A has 60 percent consumer quality preference as judged in the consumer quality comparisons. This 60 percent becomes the X value in Fig. 1;

A has 75 percent of the A + B market sales as determined from actual sales data. This 75 percent becomes the Y value in Fig. 1.

Figure 1 contains 41 points, thus representing a relationship between quality (percent consumer quality preference) and sales (percent of market sales) on 41 products.

Statistical analysis of Fig. 1 discloses that:

(1) The market is virtually devoid of any product (this company's or its competitors) which has less than 25 percent consumer quality preference.

(2) The variation in percent of market sales is much greater than the variation in percent consumer quality preference. The former extends over virtually the entire Y axis while the latter extends over only 40 percent of the X axis.

(3) Within the active range of percent consumer quality preference there is no significant correlation with percent of market sales.

Discussion of these phenomena brought out the following beliefs:

(1) A product which cannot command as much as 25 percent consumer quality preference will in short order disappear from the market for that reason alone, no matter what is done about advertising, promotion and other sales devices. This, at least, was the accepted explanation for the absence of any products from the zones of consumer quality preference below 35 percent or above 78 percent. In other words, it was concluded that there is some minimum acceptable degree of percent consumer quality preference and that outside of this range the product must perish for quality reasons alone.

(2) An added consideration enters the picture in the "acceptable" range of percent consumer quality preference. Within this acceptable range there are very large variations in percent of market sales despite small variations in percent consumer quality preference. The conclusion was that quality, though necessary, is not sufficient to generate sales, and that once the "necessary" range of quality has been achieved, the extent of sales is dominated by other factors.

There was a good deal of factual support for this theory. Company officials pointed to specific instances in which a product (either theirs or a competitor's) had achieved a "historical franchise." This is a form of consumer loyalty derived from a product's early entry into the market, and sustained by continuing an acceptable level of product and a skillful use of merchandising. In other instances, dominance in sales was attributed to specific merchandising factors, i.e., packaging, promotion, etc.

(3) Within the acceptable range of consumer quality preference, a small quality improvement is of small economic significance. This conclusion is of great practical importance.

The company Sales and Research officials were engaged in a number of projects for improving the quality of their products. Some of these projects were aimed to achieve "break-throughs," i.e., large improvements which might gain a clear advantage over competing products. However, other projects were for small improvements. As to these, there was no way of establishing their economic significance.

In particular, some of the projects were directed at raising the consumer quality preference for a given product from a value of less than 50 percent to a value greater than 50 percent, for example from 47 percent to 53 percent.* It appeared that pride, as well as the technical challenge, spurred these officials to attempt to outdo their competitors. However, the data suggested that they stood to gain more by achieving a few large improvements rather than numerous small improvements.

It is curious that in a capitalistic economy, one of the least explored areas in the Quality function has been that of Economics of Quality. It would be helpful indeed if industrial people were to share their experiences in this vital area.

*The company was fully aware of the principle of statistical significance in interpreting numbers such as this.

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What's New?

ROY A. WYLIE, *Editor*
Ampex Corporation

P-1-4—A complete line of electronic test equipment for the measurement of impedance, attenuation, and other microwave properties within the millimeter waveguide ranges has been developed by Narda. Specific equipment in K, V, Q, M, and E Bands which is now available includes Variable Waveguide Attenuators, Tuneable Waveguide Detectors, High Directivity Directional Couplers, Impedance Meters, VSWR Amplifiers, Terminations, E-H Tuners, Frequency Meters, and Waveguide Clamps and Stands. The new equipment is extremely versatile for many types of microwave measurements, due to the precision and accuracy which go into its manufacture. Particular care is taken in each step of the fabrication to assure the additional precision required for the higher frequency ranges encountered. For example, silver or tellurium copper is used as waveguide material to maintain transmission losses at a minimum. Similar precautions are taken with all other millimeter components to insure their complete reliability.

★ ★ ★

P-1-5—The Cen-Tec Armature Tester has been developed for high speed armature testing. The test unit checks with ease armature windings for shorts, opens, and grounds at a production rate of about 600 pieces per hour. In operation, the armature shaft is inserted into the bored end of the pilot rod which extends outward from the panel of the machine. As the pilot rod is pushed to its inner position, it trips a limit-switch which starts the machine test cycle. Magnetically operated radial contactors then close in on the commutator bars, completing circuits to the electronic evaluating section. The armature windings in the piece to be tested are compared with a built in standard by means of a balanced bridge circuit. Any deviation beyond a pre-set tolerance, between the standard and the test armature, results in the lighting of a red "reject" lamp. If this occurs, the part under test remains clamped in the machine until released by the operator pushing an unclamp button. If the part is accepted, a green "accept" light is lighted, the part is unclamped automatically and ejected out of the machine and onto a support cradle mounted on the front of the panel. The Cen-Tec Armature Tester may be adapted for use in testing large armatures. This adaptation makes use of a portable contact head which is connected to the machine by a suitable cable.

★ ★ ★

P-1-6—For the calibration and testing of navigational gyroscopes, such as those used in missile and rocket development, a stationary platform divorced from the earth's rotation has been developed. In effect, this new rotary table places the instrument under test, while sitting on earth, in the same environment that would exist if the instrument were resting on a stationary platform out in space. To counteract the earth's rotation, the Pratt & Whitney Rotary Table is designed to rotate at an angle correlated to a selected star's path and at a rate of speed based on intervals in the sideral day—in the opposite direction. Since it is necessary to establish very accurately the five degree intervals in the sideral day, and pass this information on to computing equipment that calibrates the gyroscope, the Pratt and Whitney table is equipped with a high precision Electrolimit Measuring System. A special rim mounted on the 24 in. standard table face plate is equipped with Electrolimit lugs spaced five degrees apart. As the table rotates, a sensing head picks up the magnetic center of each lug and passes an output signal to the computing equipment, which in turn sets up the machinery for calibrating the gyroscope. The plus and minus tolerances for various degree points from 15 to 25,000 degrees per sideral hour are held to a small fraction of one per cent. The tilt of the table is manually set and does not change during the rotational cycle. The cabinet on which the table is mounted is designed both to position the table at the most efficient working level, and also to house the two synchronous motors and the gear box that rotate the table at exactly the speed desired.

Send for Information

Additional information regarding new products or new literature items appearing in the What's New? department can be obtained by writing in the key number of the item in the Product Education Service coupon which appears on page 38.

New Literature Available

L-2-1—A new 20 page brochure entitled "Gaging Threads for High Re-

USE A QUINCUNX . . . . . .
to make your quality talk more forceful
to make your in-plant training course more effective

The Quincunx is a must for presentation of basic quality control principles. Demonstrates visually to your audience how a Normal Distribution pattern is formed. Also demonstrates how various Non-Normal distributions are formed.

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Second National Conference, Automotive Division

The ASQC Automotive Division's Second National Conference, cosponsored by the Greater Detroit section, will be held on Mar. 14, at the University of Michigan, Ann Arbor, Mich. The Conference is entitled: "Industry's Challenge—Higher Quality".

Topics and speakers all point from the various phases involved, to ways and means to achieve higher automotive quality with its rich rewards in Customer satisfaction, increased efficiency in dealer handling and service, and dollars saved in field returns.

Prominent speakers will cover the quality picture in, (1) Basic Raw Material Operations, (2) Parts Fabricators, (3) Education, (4) Major Manufacturing and Assembly Plants, (5) Personnel and Human Factors, (6) Styling and (7) Tooling and Gaging.

In addition, a Lady's Program is planned which should be of high interest to any wives who may wish to join us for the day. Advance Registrations will be necessary for the Ladies' Program in order to insure adequate transportation and facilities. A $3.00 fee will also include the Ladies' attendance at the main luncheon.

Registration fees for the entire day are $10.00 for Members of A.S.Q.C. and $12.00 for Non-Members.

It is felt that our fine program will be of value and interest to all. We hope you will join us for the day.

"American Society for Quality Control
Cleveland
May 25-27, 1959"

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liability" has been published by Pratt & Whitney Co., Inc. The brochure describes the many types of Pratt & Whitney Tri-Roll Thread Comparators and the methods by which various threads can be measured on the Thread Comparator.

• • •

Kelvin Scale is a news sheet of current information on cryogenics and related subjects, which is published periodically by Arthur D. Little, Inc. Copies may be obtained by writing The Editor, Kelvin Scale, 20 Acorn Park, Cambridge, Mass.

• • •

L-2-2—A new Gear Checker, Model 1218A, with an integral optical system for easy and accurate checking of gear leads, is described in a new four page, two-color bulletin available from Michigan Tool Co. The bulletin details design, construction and operation of this checking instrument that eliminates gage blocks, multiple settings, micrometer, verniers and gear train from the set up procedure.

L-2-3—A new product bulletin, 181-58, on the Gaertner Coordinate Comparator is available on request from Gaertner Scientific Corp. The bulletin gives a complete description of the instrument and its accessories. The coordinate comparator is used for measuring x-ray plates, spectrograms, star photographs, charged particle tracks and similar records on photographic plates. It is also used for inspecting and measuring tools, dies, mechanical parts and other opaque objects. Precision measurements can be made in either rectangular or polar coordinates.

section briefs

ALLENTOWN-BETHLEHEM . . . The Dec. 10 meeting featured Clyde L. David of the Kanarr Corp. as speaker. Mr. David discussed the use of SQC in the job shop. In the job shop there are frequently only a few pieces of an item produced with each piece sometimes being very expensive. The process capabilities and control charts are applied to an operation rather than to a product. Mr. David reminded the group of some of the essentials of a good quality control program; to make quality not inspect it, to keep production well informed, to think quality, and to use training programs. After the formal meeting was over, refreshments were served and many of the members continued to talk QC long into the evening.

BALTIMORE . . . At the December meeting, Messrs. Mindlin and Lennon of the Bureau of Old Age and Survivors Insurance, U. S. Dept. of Health, Education and Welfare, gave interesting talks on work sampling in a nation wide field organization. They described the development and application of various techniques which the bureau has used to process work load assignments efficiently and to secure statistical data.

Prior to the meeting, the fourth of seven QC basic training sessions was presented by Albert Mindlin.

BATTLE CREEK-KALAMAZOO . . . The 2nd annual management night will take place on Mar. 13 at the Sutherland Paper Co. in Kalamazoo. Carl Demrick, vice president in charge of manufacturing at the Plymouth Division of the Chrysler Corp., will be the guest speaker.

Dr. W. D. Baten will give a progress report on a section sponsored basic QC course being conducted in Galesburg.

BUZZARDS BAY . . . A round table discussion on the subject "U. S. Navy acceptance inspection procedures" was the feature of the Dec. 11 meeting. Members viewed two films concerned with the recommended QC practices necessary to assure the acceptance of material, the application of MIL-STD-105A, and the methods for evaluating the sampling risks of selected sampling plans. The application of process control charts during the production function was illustrated. A lively question period concluded the session. Hans E. Picard of the Aerovox Corp. presided. Reports were given by Walter Nichols of Aerovox, recording secretary and education chairman; and Mrs. Mary Lindenberg, awards chairman. Mrs. Geraldine Habicht of the U. S. Navy Central Torpedo Office in Newport, treasurer, was commentator for the films.

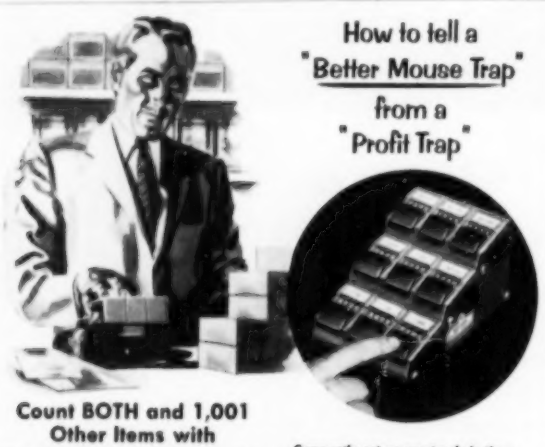
CHARLESTON . . . Dr. Grant Wernimont, Eastman Kodak Co., will be the speaker on Mar. 19. His subject will be "Precision and accuracy in methods of analysis." The meeting will be held at M. H. C. at 8 pm.

CHATTANOOGA . . . At the December meeting, W. E. Andrus, Jr., manager of the scientific computation laboratory of IBM, presented a very interesting talk on "Application of computing machines to the solution of statistical problems."

CHICAGO . . . The Furniture Mart, 666 N. Lake Shore Drive, is the site of the Mar. 18 general meeting. Miss Mae Goodwin Tarver, Continental Can Co., will be the afternoon speaker. Miss Tarver's subject will be "SQC evaluation of reliability data."

At 7:30 pm, Messrs. Godfrey, Blair, and Schneider of Inland Testing Lab., Div. of Cook Electric Co., will speak on "Fundamental concepts of reliability," touching on vendor surveillance and management's role in reliability. They will also use slides and equipment to demonstrate the purposes outlined in their talk.

CINCINNATI . . . At the December meeting Dr. Peryam, Quartermaster Food & Container Institute, spoke on "The use of sensory testing in flavor quality control." His presentation and examples on panel testing methods and preference testing methods, was interesting, informative, and hinted of benefits through more widespread application in other industrial areas. Cliff Hunt, a local tea broker, gave a most interesting talk at dinner on "The romance of tea."



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ASQC Convention Exposition Chart

13TH ANNUAL CONVENTION AND NATIONAL ALL-INDUSTRY QUALITY CONTROL & PRODUCTION EXPOSITION
CLEVELAND PUBLIC AUDITORIUM
MAY 25-27, 1959

Q to Quality

TECHNICAL PROGRAM

Fifty-nine one-hour sessions, plus six panel sessions of one and one-half hours each, will feature more than ninety speakers presenting technical papers on all that's new in Quality Control. The program has been designed with unusually broad coverage.

Among the items of special interest will be reliability and quality control in the job shop and in heavy industries. Automotive and continuous production processes will also be covered, as well as management training and inspection. A panel on electronic data processing will be featured.

The new staggered time schedule *(please examine it carefully!)* provides flexibility to registrants for attending sessions of their choice, and grants additional time to visit the Exposition and to become familiar with the many exhibits.

PLANT TOURS

Choice plant visits have been arranged from the varied selection which diversified Cleveland industry has to offer. A series of choices will be available on Monday and Tuesday afternoons. A small registration fee is required to assist in defraying some of the expenses connected with this program.

Tickets for these industrial visits may be secured in the Registration area at the Convention only. Early registration is advised because the size of the tours must be limited.

Lewis Research Lab, N.A.S.A.
Republic Steel Plant
National Carbon Research Lab
Ford Motor Co. Foundry
American Greetings Corp.
Sohio Research Lab

WELCOMING EVENING

The Cleveland section extends a cordial invitation to all early Convention registrants to attend an Open House in the Whitehall Room of the Hotel Sheraton-Cleveland from 6-9 pm, Sunday, May 24th.

Refreshments will be served and registration facilities will be available for both advance and current registrants. Representatives of the Cleveland section will be on hand to greet all visitors.

LADIES' PROGRAM

An especially active program for the ladies has been scheduled by your Host Committee. A luncheon and fashion show is planned at Higbee's. A tour of the Hough Catering Company will be held and tea will be served. The ladies will also have the opportunity to visit The Cleveland Museum of Art and have luncheon on the beautiful new terrace. The famous Cleveland May Show will be on display at this time.

Optional trips through the Cleveland Water Front, famous residential sections of Cleveland, and other points of interest will also be available. An intimate glimpse of Theatre-in-the-Round may be had at the Musicarnival, which will be open during this period.

These are only a few of the fascinating attractions which are planned for the ladies. The Whitehall Room in Hotel Sheraton-Cleveland will serve as Headquarters for the ladies throughout the Convention. A "Hospitality Hour" will be held here each morning from 9-11 am. Of course, the major social event is the "Social Evening Get-together" on Monday.

SOCIAL EVENING

The Social Evening is the traditional Get-together where you may meet old friends and make new ones. This major Convention event will be held in the Ball Room of the Hotel Sheraton-Cleveland beginning at 9 pm on Monday evening. There will be dancing and socializing. Refreshments will be on the House. This affair is open only to Convention registrants at nominal extra cost.

EXHIBITS

Our Exposition is becoming one of the most popular features of the Convention. Many registrants come primarily to see the latest in tools, techniques, methods, procedures, services, and applications. Of special interest are the latest gaging, nondestructive testing, and data processing devices. This year's National All-Industry Quality Control and Production Exposition has been expanded over previous years. A brand new staggered scheduling of technical papers has been devised to smooth out the peak attendance loads. Management, engineering, production, inspection, and purchasing people will find information to stimulate the imagination and provide practical solutions to operating problems. Quality Control and Reliability people will discover that to date this is the largest collection of exhibits devoted to their specific fields.

"SHIRT-SLEEVE" INSPECTION CLINIC

A sparkling innovation in assistance to the man on-the-job has been added to the Convention Program. This clinic, held adjacent to the exhibit area, provides the latest "know-how" and "show-how" in methods, tools, and techniques. Mechanical measurements, optical gaging, nondestructive testing, and other fields will be presented by outstanding authorities from industry, ordnance, research, and standardizing agencies. These presentations "go to the metal" to put answers in the hands of those responsible for insuring that their products stay sold.

BOOK BOOTH

This Year's Book Booth will feature the largest display of Quality Control, Statistical, and related technical publications ever prepared for an ASQC Convention.

Representatives of outstanding publishers will be present to discuss their publications with you. Competent and experienced quality control experts will be at the Book Booth to offer advice and explanation concerning different books in the field of statistical quality control, business, and experimental statistics.

An outstanding opportunity will be afforded to augment or start your statistical library.

COPIES OF TRANSACTIONS

Copies of the Transactions will be available in bound volumes for $3.00 each *only* at the Convention and *only* to Convention registrants. Copies may be obtained *after* the Convention by mail at $3.50 by writing to the American Society for Quality Control, Inc., Room 6197 Plankinton Building, 161 W. Wisconsin Avenue, Milwaukee 3, Wisconsin.

Dick Race, QC manager, U. S. Playing Card Co., and D. C. Flischel have successfully concluded the 1958 fall education program. Mr. Race taught the elementary course and Mr. Flischel taught the intermediate course. Student questionaires indicated a widespread application of the principles learned.

CLEVELAND . . . With the holiday season in mind, the section held a ladies' night on Dec. 5. The good turnout enjoyed a presentation by Mrs. Mavis B. Carroll of the General Foods Corp. In terms understandable to all, Mrs. Carroll described the techniques and results obtained in evaluating various food items.

COLUMBUS . . . Richard Anderson, Battelle Memorial Institute, was the speaker at our social evening meeting held Dec. 5 at the Desert Inn. His talk, "The international geophysical year," was very enlightening and interesting.

A joint meeting with the Columbus section of ASME was held Dec. 11 at Battelle Memorial Institute. The DoALL Co. presented an illustrated lecture on "The story of the cutting edge."

Burr Stanton, project engineer at the General Electric Co., will be the speaker at the Mar. 18 meeting. Mr. Stanton's subject will be "Installing a new system of design, production, and machine control." He will describe a method for controlling at the outset all factors that enter into quality production, design, and machine tooling.

CORNING-ELMIRA . . . The section would like to express its thanks to the personnel of the newly constructed Big Flats plant of the Corning Glass Works for the successful tour of their plant on Dec. 9. Approximately 50 members and guests were in attendance to view the operations of the largest plant in the world manufacturing laboratory and chemical glassware.

DALLAS-FORT WORTH . . . On Dec. 15 the section combined a tour of Texas Instruments' new semiconductor-components division plant with the regular monthly meeting. The meeting was held in the division's spacious and beautiful auditorium. Dr. A. W. Wortham, QC manager of the division and junior past chairman of the section, welcomed the 65 members and 85 guests who attended. Fred Snyder gave a general description of the plant and its special features, describing the plant as a "pattern for a dynamic future." Dr. Leroy Folks brought a very interesting talk on "Statistical methods in the semiconductor industry." The group was then divided into smaller groups of 10-12 each and escorted through the division by QC personnel. After the tour, refreshments were served to a very tired but well pleased group.

DANVILLE-SUNBURY . . . The executive board is working to begin some excellent courses in SQC on the Bucknell University campus.

DELAWARE . . . A very successful meeting was held in December. The section was fortunate to have two main speakers for the evening. Charles Pike, works manager of International Latex Corp. spoke on how QC has helped International Latex and just how it fits into the overall manufacturing team. He also related some of his experiences with QC in other companies with which he has been associated.

Paul Clifford, professor of mathematics at Montclair State Teacher's College, gave his views on what QC is today, and the direction he feels it should take in the next five years. The good question and answer period which followed the two speakers' presentations revealed the enthusiastic interest which they aroused.

The clinic session prior to dinner was conducted by R. G. Mitchell of International Latex Corp. Mr. Mitchell presented a case study on "Attribute defect prevention" through scatter diagram analysis.

The Mar. 5 meeting will be highlighted by the presence of Wallace J. Richardson, associate professor of industrial engineering at Lehigh University, who will speak on work sampling. The clinic session will be conducted by Paul Doehlert of the mathematics and statistical group of the DuPont Co., who will speak on "Design of experiments" and present a case study.

DENVER . . . On Dec. 11, 35 members and guests met at the Oxford Hotel. George Sandenburg of Hill McCanna Magnesium Foundry, gave a talk with slides on the application of QC in a magnesium foundry.

EVANSVILLE-OWENSBORO . . . The December meeting consisted of an extremely interesting tour of the Potter & Brumfield Co. where many different types of relays are manufactured. The tour was conducted by Fred Wilhite, QC manager of Potter & Brumfield and section vice president.

The Mar. 17 meeting will be held in Owensboro. The speaker will be Fred J. Berkenkamp, QC engineer for the General Electric Co. Mr. Berkenkamp's subject will be "Quality system measurements."

GREATER DETROIT . . . The second annual ASQC Automotive Division conference, co-sponsored by the section, will take place Mar. 14 at the University of Michigan in Ann Arbor. The conference will be dedicated to "The industries' challenge—higher quality."

High warranty costs e a major concern of the automobile manufactures of today; along with, of course, related costs such as excess scrap and rework. This conference will be beamed at the cost of failure as seen from the viewpoint of engineering, purchasing, manufacturing, and quality control.

GREATER MUSKEGON . . . Ninety-two members and guests of the section, the Grand Rapids section of ASQC, and the Holland-Zeeland Management Club met in joint session at Cumerford's Restaurant in Holland on Dec. 11 to hear Dr. A. V. Feigenbaum of the General Electric Co. His topic, "QC principles," was a challenge to management and QC technicians. Merrill Bailey, section chairman, and Harold Maat, management club president, presided at the meeting.

The Mar. 12 meeting will be the section's annual shrimp and fish dinner at the Mona Lake Boat Club. Everyone takes their hair down at this meeting—casual clothes are in order and the evening's program is completed by a well-planned panel discussion on a particular phase of QC.

Bert Taulbee has announced that a course of instruction in elementary QC is being conducted by Glenn Bailey and William Poe.

HAMILTON . . . Christopher B. Lewis of Firestone Tire & Rubber Co. was the speaker at the Dec. 11 meeting. A particularly interesting film showing operations at Firestone highlighted the meeting.

A large turnout is anticipated for the Proctor & Gamble plant tour which is scheduled for Mar. 12.

HAMILTON-MIDDLETOWN . . . The Dec. 10 meeting proved to be an interesting as well as educational meeting. Stephen Adams talked on the topic "Installation of QC in existing organizations." He emphasized his material with a visual presentation. He contributed many useful ideas in the areas of selling management, organizing for QC, and installation of a QC program. Mr. Adams is the inspection supervisor of the Wolverine Tube Division of Calumet and Hecla, Inc.

OUR EVER-GROWING FAMILY

With the additions of St. Petersburg-Tampa (Fla.), Orlando-Cape Carnaveral (Fla.), and Akron-Canton (Ohio) the number of sections in the Society is now 109. The Society is proud to extend a most cordial welcome to these new sections.

107—St. Petersburg-Tampa (Dist. 15)

Chairman: Rocco P. Caruso
Electronic Communications, Inc.
St. Petersburg, Fla.

Vice Chairman: Calvin C. Newton
General Electric Co.
St. Petersburg, Fla.

Secretary: Gilbert R. Stone
Electronic Communications, Inc.
St. Petersburg, Fla.

Treasurer: William R. Royall, Jr.
General Electric Co.
St. Petersburg, Fla.

108—Orlando-Cape Carnaveral (Dist. 15)

Chairman: John L. Kidwell
The Martin Co.
Orlando, Fla.

Vice Chairman: William E. Rooney
Miller-Rooney Plastics
Orlando, Fla.

Secretary: Philip B. Crosby
The Martin Co.
Orlando, Fla.

Treasurer: O. F. Sella
Radiation, Inc.
Orlando, Fla.

109—Akron-Canton (Dist. 8)

Chairman: Donald L. Dewing
The General Tire & Rubber Co.
Akron, Ohio

Vice Chairman: Robert W. Dorn
Timken Roller Bearing Co.
Canton, Ohio

Secretary: Clarence A. Ritchie
B. F. Goodrich Co.
Akron, Ohio

Treasurer: Lawrence A. Bedford
Goodyear Tire & Rubber Co.
Akron, Ohio

HARRISBURG . . . Despite a cold night, over 50 members braved the weather to hear J. Fred Verigan, manager of QC at Crown Cork & Seal Co. Mr. Verigan gave a most informative talk on "Selling plant personnel on QC." Those attending left the meeting with many new approaches to this common problem. No summary of the meeting would be complete without mention of the excellent dinner which was served by Hostetter's in Mount Joy.

Plans are underway for the annual ladies' night to be held Mar. 4. With Miss Bonnie Small as the star performer, another record crowd is expected to attend the dinner meeting to be held at the Brunswick Hotel in Lancaster. The arrangements committee, under the capable chairmanship of Bob Naylor, has some surprises and door prizes for the ladies. This is an opportunity for your wife to meet your ASQC friends so let's have a big turnout.

HARTFORD . . . Because of two recent developments, the place and speaker for our March meeting must be changed. Robert Lusser, scheduled speaker, has left the Redstone Arsenal to take a new position in Germany. The second item was the destruction of the Club Alden by fire. The replacement speaker and new meeting place are to be announced in a meeting notice which will be sent to each member.

Albert Aubin, manager of QC for the Underwood Corp., spoke on "Predictable quality" at the December meeting. He stressed the necessity, in order to obtain predictable quality, of establishing quality controls from the very beginning of manufacturing processes, the relationship between manufacturing quality and final quality, particularly as regards to reliability of the final product.

HUNTSVILLE . . . Edward Balog, U. S. Steel Corp., presented a talk on "The nature of QC" at a recent meeting.

INDIANAPOLIS . . . On Jan. 20 (officially proclaimed as "Quality Control Day in Indianapolis" by Mayor Charles Boswell) the section was pleased to have as its speaker H. J. Jacobson, quality control consultant. Mr. Jacobson's subject was "QC as a profession," a subject he is surely qualified to speak on.

A familiar sight to those attending the 13th Midwest QC Conference at Kansas City was the booth publicizing the 14th Midwest QC Conference to be held in 1959 at the beautiful French Lick Sheraton Hotel, French Lick, Ind. The booth was the result of the combined work of John Waldner, section chairman and chairman of the 14th conference, and publicity chairman George Blackburn. Mr. Waldner and Mr. Blackburn are with Eli Lilly and Co. From all indications, the booth was a very successful venture and from comments received, a good turnout is expected.

KANKAKEE-JOLIET . . . Winston C. Dalleck of McKinsey & Co. spoke Dec. 1 on the use of statistical sampling in airline accounting departments. Ticket exchange between most large airlines is based on a random ten percent sample of all tickets to be exchanged. This reduces handling costs tremendously with only a slight increase in error.

LOUISVILLE . . . The December meeting was held at the U. S. Naval Ordnance plant. Twenty-six members were present for a luncheon. Capt. Butler gave a warm welcome to the group and presented a summary of the plant operations. The hosts, Ed Mickey and Ray Donnally, then conducted a tour lasting several hours. On the tour the group was shown and explained the details of constructing, inspecting, and testing the various parts in production. We would like to thank Ed Mickey and all concerned for a very informative and interesting tour.

MEMPHIS . . . The December meeting was held at Memphis State University. The section was honored in having David S. Chambers as the speaker. Mr. Chambers encouraged and assisted the founding of the Memphis section. He teaches QC and statistics at the University of Tennessee and serves the Society as chairman of the Committee on Education and Training. His topic was "Control for largest and smallest values."

METROPOLITAN . . . On Mar. 19, the section is repeating a general meeting format which proved a tremendous success last year. In this unusual "buzz session" meeting, which is to be held at the Hotel Shelburne in New York City at 7:45 pm, those attending are divided into broad occupational categories and relatively small groups. Each group will have its own chairman and plans call for some panels to be chaired by production executives. The topic, "Selling QC to management," should result in interesting and stimulating group discussions where everyone has an opportunity to voice an opinion. The meeting will be keynoted and the opinions summarized by C. D. Ferris of Mohasko Industries, Inc.

The Princeton Conference in December was well attended. The luncheon speaker was Dr. Gertude Cox, director of the Institute of Statistics of North Carolina, who spoke on the "Growth of applied statistics." W. J. Youden of the Bureau of Standards spoke at the social on "statistics" in general.

MID-HUDSON . . . Forty-three members and guests attended the Dec. 4 dinner meeting which was held at the Hotel Kingston. The guest speaker was Sid Fielden of IBM whose topic was "Statistical dimensioning." Mr. Fielden explained the use of this improved technique through charts which made the process readily understood.

The speaker for the Mar. 3 dinner meeting will be E. C. Harrington, Jr. who will speak on "Response surface experimentation."

MONTREAL . . . On Dec. 10 Dr. P. J. Sandiford, Trans Canada Airlines, addressed the section and visiting members of the Montreal Operations Research Society. Dr. Sandiford told of the interrelationship of OR and QC and what future the field of OR held for QC engineers.

On Dec. 18 a special meeting of the executive was held to make plans for a management night meeting.

On Feb. 25 a plant tour of the aircraft plant of Canadair, Ltd., St. Laurent, is scheduled.

Miss Mildred N. Torrey, Bell Telephone Labs, will be guest speaker at the Mar. 18 meeting. Her topic will be "Selection of samples for a purpose."

MUNCIE . . . Thursday night, Mar. 19, will mark another outstanding meeting. Mel Linder, industrial and statistical engineer of the Owens-Illinois Glass Co., will address the group. His paper is entitled "Developing probability curve for double sampling." The address will be presented at 7:30 pm in the Pine Shelf Room of the L.A. Pittenger Student Center on the Ball State Campus. The dinner meeting preceding the address will convene at 6:30.

NEW HAVEN . . . Our Mar. 10 meeting will be held at the Southern New England Telephone Co., Conference Room, 227 Church St. The subject to be discussed will be "New developments for the industrial statistician." James Dallay,

(Continued on page 32)

MODEL CS-102

ROLL RUNOUT INDICATOR

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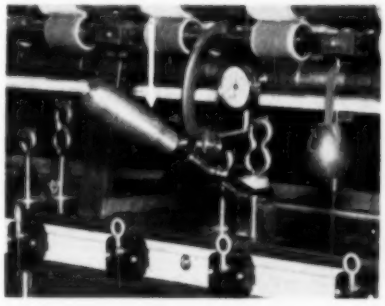
West Point Mfg. Co.



This unit is used for checking the runout or eccentricity of both top and bottom spinning rolls and roving rolls in textile mills. Roll runout causes a loss of skein strength and an increased non-uniformity in the yarn. The magnetic base holds the unit in position so that the dial indicator will rest at approximately the center of the roll and normal to the surface of the roll. As the frame is running, the fluctuations of the Dial Indicator will read the runout which is twice the eccentricity.

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SECTION CALENDAR (FEBRUARY 25—MARCH 31)

SECTION	DATE	PLACE	TIME	SUBJECT	SPEAKER
Allentown-Bethlehem	Mar. 21	Hotel Traylor	8:30 am	Joint 5th District Industrial QC Conference	———
Baltimore	Mar. 17	Baltimore Memorial Stadium	8:15 pm	Variables Sampling Plans	Max Astrachan, USAF Institute of Technology
Battle Creek-Kalamazoo	Mar. 13	Sutherland Paper Co., Kalamazoo	8:00	Management Night	Carl Demrick, Plymouth Div., Chrysler Corp.
Boston	Mar. 16	M.I.T. Faculty Club, Sloan Bldg.	———	Joint Meeting with Industrial Eng. Society	Panel Discussion
Buffalo	Mar. 30	Norton Hall, Univ. of Buffalo	6:30	What Industry Expects of a QC Engineer	Marsh B. Gwyn, Eastman Kodak Co.
Buzzards Bay	Mar. 10	Continental Screw Co.	8:00	Quality Control	F. G. Fales, Sylvania Corp.
Charleston	Mar. 19	M. H. C.	8:00	Precision and Accuracy in Methods of Analysis	Grant Wernimont, Eastman Kodak Co.
Chattanooga	Mar. 10	Hotel Patten	6:30	QC in Chattanooga Industry	J. B. Baity, W. H. Corwin, S. F. Torbett
Chicago	Mar. 18	Furniture Mart	5:00	General Meeting	———
Cincinnati	Mar. 18	Engr. Soc. Bldg.	8:00	Fundamental Application of QC in the Chemical Industry	L. K. Reitz, Eastman Kodak Co.
Cleveland	Mar. 6	Cleveland Eng. & Scientific Center	8:00	Queuing and Other Aspects of OR	Dr. Jack Little
Columbus	Mar. 18	Westinghouse Electric Corp.	8:00	Installing a New System of Design, Production, and Machine Control	Burr Stanton, General Electric Co.
Corning-Elmira	Mar. 10	Langwell Hotel, Elmira	7:00	Control Charts Without Calculation	Prof. Paul C. Clifford, Montclair State Teachers College
Dallas-Fort Worth	Mar. 12	Arlington State College, Arlington	8:00	The Nature of QC	Leon Bass, General Electric Co.
	Mar. 14	Southern Methodist University, Dallas	8:00 am	Fourth Annual QC Symposium	12 speakers
Delaware	Mar. 5	Lord De La Warr Hotel, Wilmington	8:00 pm	Work Sampling	Wallace J. Richardson, Lehigh University
Erie	Feb. 25	———	———	How Managements Have Drastically Reduced Operating Costs	Dorian Shainin, Rath & Strong, Inc.
Evansville-Owensboro	Mar. 17	Owensboro	6:30	Quality System Measurements	Fred J. Berkenkamp, General Electric Co.
Greater Detroit	Mar. 14	University of Michigan	9:00 am	2nd Annual ASQC Automotive Division Conference	———
Greater Muskegon	Mar. 12	Mona Lake Boat Club	6:30 pm	Army Ordnance Quality Program	Panel Discussion
Hamilton	Mar. 12	Proctor & Gamble	8:00	Plant Tour	———
Hamilton-Middleton	Mar. 11	Anthony Wayne Hotel	6:30	How Managements Have Drastically Reduced Operating Costs	Dorian Shainin, Rath & Strong, Inc.
Harrisburg	Mar. 4	Brunswick Hotel	6:45	The Inside Story of QC	Miss Bonnie Small, Western Electric Co.
Hartford	Mar. 17	———	———	———	———
Huntsville	Feb. 26	———	———	Life Testing	Dr. A. C. Cohen, University of Georgia
	Mar. 26	Decatur	———	Plant Tour	———
Indianapolis	Mar. 17	Atherton Center, Butler University	6:30	Reliability and QC	Robert R. Wendt, Bendix Products Division
Kankakee-Joliet	Mar. 3	Maple Manor, Kankakee	6:30	Canning Control	G. O. Bunch, U. S. Carbide & Carbon Co.
Los Angeles	Mar. 12	Rodger Young Auditorium	6:00	Recent Advances in D.O.D. QC Policy	John J. Riordan, Department of Defense
Louisville	Mar. 9	Speed School	8:15	Stock Market Analysis	Paul Dysert
Metropolitan	Mar. 19	Hotel Shelburne, New York	7:45	Selling QC to Management (Buzz Session)	C. D. Ferris, Mohasko Industries, Inc.
Mid-Hudson	Mar. 3	Poughkeepsie	7:00	Response Surface Experimentation	E. C. Harrington, Jr., Monsanto Chemical Co.
Montreal	Feb. 25	Canadair, Ltd., St. Laurent	———	Plant Tour	———
	Mar. 18	CIL Bldg.	8:15	Selection of Samples for a Purpose	Miss M. N. Torrey, Bell Telephone Labs
Muncie	Mar. 19	Student Center	7:30	Developing Probability Curve for Double Sampling	Mel Linder, Owens-Illinois Glass Co.
New Haven	Mar. 10	Southern NE Telephone Co.	8:00	New Developments for the Industrial Statistician	James Dallay, General Electric Co.
Northeastern Indiana	Mar. 12	Chamber of Commerce, Fort Wayne	———	All-Day Conference	———
Omaha-Lincoln	Mar. 13	Lincoln	7:00	SQC in Glass	A. P. Stergion, Corning Glass Works
Parkersburg	———	First Federal Bldg.	8:00	Multi-level Continuous Sampling Plans	D. C. Flischel, General Electric Co.
Pittsfield	Mar. 11	Stanley Club	9:00 am	Practical Management of a QC Program	C. W. Carter, Rath & Strong, Inc.
Pittsburgh	Mar. 24	Wood St. YWCA	6:30 pm	Role of QC in Reliability Testing	Robert L. Brickley, Westinghouse Electric Corp.
Portland	Mar. 3	———	7:30	Psychology and its Use in QC	H. Blood, Omark Industries
Rhode Island	Mar. 19	Prov. Eng. Soc. Bldg., Providence	8:00	SQC in Manufacturing	Charles A. Bicking, Carborundum Co.
Rochester	Mar. 3	Chamber of Commerce	6:15	Evaluation of Distortion of Photographic Lenses	Dr. F. E. Washer, National Bureau of Standards
	Mar. 26	University of Rochester	———	15th Annual Clinic	———
St. Charles	Mar. 17	Club Arcada	4:00	Process Controls—Attributes	Prof. H. R. Swenson, Illinois Institute of Technology
			6:30	Use of Variables Measurements in Reliability Studies	Ralpn Haertel, Warwick Co.
St. Louis	Mar. 18	Golden Fried Chicken Loaf Restaurant	6:30	What's Behind Experimental Design	Richard Bingham, Jr., Carborundum Co.
Salt Lake City	Mar. 11	Union Bldg., University of Utah	7:30	Panel Discussion—Organizing for an Effective Reliability Program	———
San Antonio	Mar. 10	Hilton Hotel	8:00	Quick and Easy QC for the 200 and under Manufacturing Firms	James L. Coburn, Convair-Ft. Worth
San Francisco Bay Area	Mar. 9	Ramor Oaks	6:30	QC Philosophies in the Defense Department	Joint Air Force-Army-Navy Panel
South Bend-Mishawaka	Mar. 12	Bendix Legion Post, South Bend	7:30	Forum	J. F. Gyoles, Bendix Products Division
	Mar. 19	Bendix Legion Post, South Bend	7:30	Measurement and QC Costs	W. J. Masser, General Electric Co.

State Univ. of Iowa	Mar. 4-5	Midwest Mfg. Corp., Galesburg, Ill.	9:00 am	Two-Day Meeting	——
Syracuse	Feb. 28	Yates Hotel	12:30 pm	Engineering in the Space Age	——
	Mar. 24	Turn Hall	6:30	Student Night	——
Toledo	Mar. 12	Angelo's	6:30	100 Percent Inspection—Its Strength and Weakness	Dorian Shainin, Rath & Strong, Inc.
Toronto	Mar. 7	Hart House, Univ. of Toronto	——	All-Day Forum	——
	Mar. 25	Avro Aircraft, Ltd., Malton	7:30	Plant Tour (security classification) by Invitation	——
Tulsa	Mar. 16	Borden's Cafeteria, Sheridan Village	——	Short Run QC	Leon Bass, General Electric Co.
Univ. of W. Ontario	Mar. 11	YMCA, London	8:00	Production Views QC	——
Utica	Feb. 26	Hotel Hamilton	7:00	Joint Meeting—Eng. Assoc. of Mohawk Valley	——
Washington, D. C.	Feb. 25	Occidental Restaurant	6:30	ASQC and Professional Status	Dr. A. V. Feigenbaum, General Electric Co.
Windsor	Mar. 11	Canadian Rock Salt Co.	——	Mine Tour	——
Youngstown	Mar. 5	Astoria Cafe, Warren	6:30	Clerical Shortcuts for QC Engineering	R. G. Patterson, U. S. Ceramic Tile Co.

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(Continued from page 29)

General Electric Co., will be the speaker. This should prove to be a very interesting meeting and we are looking for a large turnout.

NORTHEASTERN INDIANA . . . A very successful training program was started this season at the Dec. 11 meeting under the chairmanship of Max Comerford. Fundamental training in QC methods was continued for one hour prior to the principle speaker and plans are being made to provide this attraction in all programs this season.

OMAHA-LINCOLN . . . The annual ladies' night was held Dec. 12. Members and their ladies met at Marchio's in Omaha for dinner. George Woodward gave a very interesting talk and showed pictures about his recent trip to Russia.

PARKERSBURG . . . No regular meeting was held in December due to the holidays. The officers met at the Howard Johnson Restaurant for a business session.

PHOENIX . . . The December meeting was a dinner meeting held at the Sky Riders Hotel on Dec. 12. With wives in attendance, an exceptionally large group heard M. Sallisbury speak on "QC and the diodes" and watched a film strip on the "Space frontier." The subject of the film was also the subject of a talk by Dr. F. W. Schwarz of the U. S. Semiconductor Co. which followed the showing of the film.

The section has just recently completed a training course entitled "The professional QC engineer." Fifty-eight people attended one or more sessions which were intended to promote the professionalism of QC.

PITTSFIELD . . . "QC and me" was the subject of the Dec. 3 meeting. The program featured presentations by F. C. Hartwell of the Peter J. Schweitzer Div., Kimberly-Clark Corp. and John J. Landers of General Electric Co. Mr. Hartwell reviewed the principal activities of a staff QC group in multi-plant manufacturing operations, as well as line QC functions within each individual plant. Mr. Landers described the quality control operation in the missile and ordnance field. Both speakers stressed the importance of the concept of "total QC" and cited several practical examples of the activities of their groups.

The Mar. 11 meeting will be an all-day session the theme of which will be "Practical management of a QC program." C. W. Carter of Rath & Strong, Inc. will conduct the session.

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7th Northwest Conference for Quality Control

On Apr. 3-4, the 7th Northwest Conference for Quality Control will be held in Portland, Ore.

The technical sessions will feature: Frank Squires, Topp Industries, Inc.; Leon A. Aroian, Hughes Aircraft Co.; De Alquez, Mariani Foods; and John Jaech, General Electric Co. The topic of Mr. Squires' talk will be "Recent results in the theory of QC charts." Mr. Aroian will present "What makes a QC chart tick." An open topic on food quality control will be presented by the food expert. Mr. Jaech will discuss "Fractional replication."

The results of the recent professionalism survey conducted on the west coast will be another feature of the conference. Several movies are also planned as added attractions.

A complete training session will be designed to acquaint those who are interested in QC and desire knowledge of the basic tools used in QC. The instructors for the training phase of the conference are top men in their fields.

The entire conference is geared to give all those who attend a greater insight into just how QC can be applied to their individual situations in industry.

PITTSBURGH . . . The Dec. 9 meeting was held at the Wood Street YWCA. This was a joint meeting with the local section of ASA. A. M. Schneider of American Cyanamid Co. spoke on "Applications of multivariate analysis." He discussed the analogy of multivariate analysis to the usual "t" test for differences between two means as well as the case of a two factor analysis of variance. The talk was most informative and a lively discussion period followed.

The Mar. 24 meeting will be held at the Wood Street YWCA with dinner at 6:30 pm followed by the program at 8. Mr. Robert L. Brickly of the Westinghouse Electric Corp., Semiconductor Plant, will speak on the "Role of QC in reliability testing."

PORTLAND . . . The Portland Chamber of Commerce has been very helpful in informing us of the most advantageous time for a convention—Apr. 3-4 will be the date. No other conventions will be here at that time. A number of outside speakers have confirmed their acceptance to attend the conference. Bob Menstell, Osborne Electronics, is doing a terrific job in directing, amalgamating, and coordinating the myriad of details involved in making this conference the best yet. The executive committee is attempting to select the most distinctive and original registration folder that will be a Portland section trade mark. The 7th N. W. Conference for QC is to be a bi-mode conference—a technical session and a training session. Dr. Worthington of Oregon State College has almost completed the training outline for the conference.

RHODE ISLAND . . . At our regular meeting held on Dec. 19 Alan Stone, QC manager of the refractories plant of Corning Glass Works, gave a talk on the psychological approach which was used to install their QC program. He also outlined the defect prevention program in a most interesting manner.

ROCHESTER . . . Harry Smith of Proctor & Gamble gave a very interesting talk on multivariate analysis on Dec. 2 before the technical sub-group. After the meeting, many of the group adjourned to the home of Richard Freund where discussions were continued. Mr. Smith had with him his associate at P & G, Dr. Ram Gnana Desikan, who took an active interest in the discussion.

On Dec. 8 Dr. Amihud Kramer of the University of Maryland discussed "Specifications and sampling techniques" with the food and beverage industries sub-group.

On Dec. 16 Prof. Gerald Nadler, Washington University, gave a very informative talk on "QC techniques in work measurement" at a joint meeting of the section and IES.

On Mar. 3 the gaging and measurement sub-group will meet with Dr. Francis E. Washer, chief, optical instruments section, National Bureau of Standards. Dr. Washer will deal with the "Evaluation of distortion of photographic lenses."

The big day for the section is Mar. 26. The 15th annual clinic will be held at the University of Rochester. A broad program, covering all phases of SQC and related subjects, has been planned.

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ST. CHARLES . . . On Dec. 10 a tour was made of the Shakeproof Div., Illinois Tool Works, Elgin, Ill.

On Mar. 17 Ralph Haertel, QC engineer at the Warwick Co., will address the dinner meeting on the subject "Use of variables measurements in reliability studies." Mr. Haertel's talk will be preceded by a pre-dinner session seminar conducted by Prof. H. R. Swenson, Illinois Institute of Technology, on the subject "Process controls—attributes."

ST. LOUIS . . . On Dec. 3 the section toured the Alton Box Board Co. The tour was very informative and beneficial to all those who attended.

SALT LAKE CITY . . . The Dec. 11 meeting held at the University of Utah consisted of two interesting lectures. Prof. Claren Nelson, University of Utah, presented a dissertation on "The theory of errors." He defined the types of error normally occuring in defining a set of universe parameters. He further enlarged on the use of methods designed to reduce bias generated by error to a minimum.

D. R. Mabey, Utah Copper Div., Kennecott Copper Corp., presented a lecture highlighted by the use of lantern slides on Kennecott's "Progress through scientific development." He discussed the open pit mining and low grade ore processing accomplished in the Utah facility for the highly competitive market. Both past accomplishments and anticipated method advancements were discussed. Particular reference was made to Kennecott's recently organized QC department, its development, and its anticipated use in defining and meeting goals in the future.

SACRAMENTO . . . Here are a few highlights of 1958. In September, chairman Clarence Bobbs called a reorganization meeting. New members were welcomed, committees appointed, and plans for 1958-59 formulated. October—Orville Bramble, McClellan AFB, made an interesting and instructive presentation on "Management quality reporting system." November—Seventy-two members and friends heard Frank H. Squires, Topp Mfg. Co., speak on "The future of QC." December—Members and their wives enjoyed a festive Christmas dinner-dance in the Cabana Room of the Eldorado Hotel. Aerojet's Charles Parker chairmaned the happy gathering.

Program chairman John P. Welsh, Aerojet-General Corp., has announced interesting programs scheduled for the future.

Sacramento, the 100th ASQC section, is on the upbeat and organization is in high gear.

SAN ANTONIO . . . The section has passed a most successful half-way point during this season's programming. The remaining scheduled programs are sure to be as effective and interesting. The program chairmen of the Texas sections are again planning a joint meeting for the purpose of arranging "circuit tours" for the 1959-60 season. The South Texas section (Houston) will be the host section for this meeting. The San Antonio section will be host section in 1960 at a meeting to be held in conjunction with our one-day conference.

SAN DIEGO . . . The section has already passed last year's membership total and is steadily growing. Attendance at the meetings was never better and enthusiasm is riding high. By way of reaffirming the social aspects of our association and also to "blow off a little steam" we are planning a spring dinner dance for members and guests. We are looking forward to a festive evening.

SAN FRANCISCO BAY AREA . . . Dr. Robert Bechhoffer of Cornell and Stanford Universities spoke to the section at a dinner meeting held at the International Inn on Dec. 8. His talk on multiple decision procedures for ranking means of normal populations with a common known variance, was most informative and was enjoyed by 40 members and guests.

SOUTHERN CONNECTICUT . . . The section had one of the most inspiring meetings to date. The fact that C. E. Fisher, Society President, was the guest speaker proved beyond a doubt that the members are very interested in seeing and hearing their Society officers. Mr. Fisher discussed the "Professional status of the QC engineer." This discussion was in line with the major aims of the Society presently being carried out by the Committee on Professional Development.

The members took good advantage of this rare opportunity to meet their Society President. Mr. Fisher's progressive talk brought forth an extended discussion period which was proof positive that this subject is of vital importance to everyone working in or related to the field of QC. We feel very proud that this section was honored with his presence.

SOUTH TEXAS . . . On Dec. 5 the section enjoyed a 240 mile round trip field excursion to Lufkin and Diboll, Texas. The group visited Texas Foundries, Southland Paper Mills, and Tempboard Division of Southern Pine Lumber Co. Everyone was privileged to visit two of the three plants.

STATE UNIVERSITY OF IOWA . . . The fall meeting was held Dec. 4-5. A plant tour of the large implement manufacturing facilities of the Deere & Co., Ottumwa Works, was followed by a paper presented by J. Schlier, Jr., Deere & Co., on the "Use of regression: correlation techniques in budgeting." An evening paper "Has QC satisfied our reliability problems?" was presented by H. Harrison, Collins Radio Co. The following morning Dr. Hicks spoke on "Some statistical aspects of inventory control."

Our winter meeting will be held Mar. 4-5 at Galesburg, Ill. This will include a plant tour and presentation of three papers.

TENNESSEE . . . Congratulations are due the section's members for achieving second place in the Society's membership renewal contest. Fine work, fellows!

Section chairman H. F. Littleton has recently submitted our formal approval for the organization of a section in Kingsport. At a second organizational meeting, the group which now numbers 38 elected the following officers: Hubert M. Hill, Chairman; Carl L. Wilson, vice chairman; Joseph T. Johnson, secretary; and Myles E. Duellman, treasurer. As a direct result of their efforts in that area, 20 new members have been added to the roll.

Appointments to the section examining committee for the year are David S. Chambers (chairman), H. Alan Lasater, and H. F. Littleton.

TOLEDO . . . The section joined with other engineering societies in Toledo on Dec. 11 at the Toledo Edison Club for the annual husband-wife Christmas party. This was another successful effort of the Engineering Societies of Toledo on a combined effort to organize as a whole. The affair was well attended and dinner was followed by dancing.

TORONTO . . . The Christmas Stag was held at Little Denmark on Dec. 22 and proved a huge success. The evening was highlighted by a film dealing with the development and subsequent manufacture of the Avro "Arrow."

The sixth annual forum will be held at Hart House, University of Toronto, on Mar. 7. As in previous years, one of the outstanding features will be an all-day basic training course in SQC to be presented by W. A. MacCrehan, manager of QC, Aviation Electronic Products, Bendix Radio Corp. We are also introducing a two-hour panel discussion moderated by A. P. Deacon of Deacon and Associates. In

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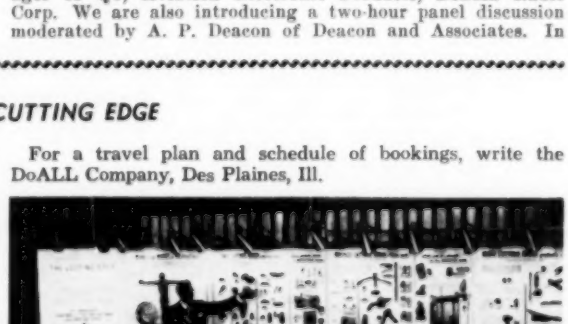
For a travel plan and schedule of bookings, write the DoALL Company, Des Plaines, Ill.



addition, thirteen other sessions are scheduled embracing many aspects of QC within industry.

TUCSON . . . Dr. Joseph E. King, internationally known industrial psychologist, spoke at the December meeting on methods of personnel selection for QC. He pointed out the importance of aptitude-intelligence scores and certain other personality and background traits in selecting inspectors, office-technical and engineering help. Scientific personnel selection methods, according to Dr. King, are becoming increasingly important, taking into account such factors as investment in new-hires, turnover, capital investment, and fringe benefits. Normal to high scores were indicated as desirable on aptitude-intelligence tests, including factors such as comprehension, systems manipulation, perceptual speed, judgement, fluency of expression, memory, space relations, and motor coordination. Statistical methods were discussed in analyzing these factors.

New officers for the section were installed. They were: chairman—Mark Manning, vice chairman—Warren Clemens, treasurer—W. J. Anderson, and secretary—Ella Scofield.

TULSA . . . We have had several fine lectures recently. In addition, our first educational course was completed with certificates issued to those completing the course. Plans are now being laid for the start of the second course.

The first advance publicity notices for our all-day forum were released.

Emmett Main, Air Force QC at Douglas Aircraft, has accepted the program chairman's job for the coming year. The nominating committee has been appointed with K. C. Jung as chairman.

UNIVERSITY OF WESTERN ONTARIO . . . A very successful management night dinner meeting was held on Dec. 10. Approximately 100 members and guests heard C. A. Pollock, president of Dominion Electrohome Industries, Ltd. give an opening address "QC in industry—today and tomorrow." Mr. Pollock was followed by Warren R. Purcell, director of QC for Raytheon Mfg. Co., who presented his talk "Who controls quality—and how." It was generally acknowledged that this meeting was the highlight of the season program.

WASHINGTON, D. C. . . . Section members are looking forward to an active end-of-the-month. The regular February meeting featuring A. V. Feigenbaum of the General Electric Co. will be followed closely by the third annual conference of the Society's Administrative Applications Division, Mar. 5-6, Georgetown University. The conference, titled "Science in management," will cover various applications of sampling probability theory and operations research and will present leading authorities from business, government, and education.

WICHITA . . . Charles W. Hesse, works manager, Commercial Aircraft Division of the Cessna Aircraft Co., was the speaker at the Nov. 4 dinner meeting at the Shirkmere Hotel. The subject of his discussion was "What price quality."

On Dec. 2 M. J. Bratt, QC engineering specialist of the General Electric Co., was the visiting speaker at a dinner meeting at the Lassen Hotel. Mr. Bratt discussed statistical methods in ultra-sonic inspection.

WINDSOR . . . The section had an enjoyable evening during the children's annual Christmas party. Santa made his entrance after Jim McMillan led the group in an inspirational and vociferous sing-song. Santa carried in two bags of presents—one for the children and one for George Smith's family. Thanks were passed on to the individuals who created and organized the party. Ross Gowin in turn thanked Jim McMillan for his part as MC on behalf of the group. (Several members were observed making two trips to the buffet table for the high quality roast beef.)

The Mar. 11 meeting will feature a mine tour of the Canadian Rock Salt Co.

YOUNGSTOWN . . . On Dec. 4 the section visited the Warner & Swasey Co. to tour the Gradall Mfg. plant. This operation is really divided into two plants, one being the machining plant while the other is the Gradall fabrication and assembly plant. In the machining plant all parts for the Gradall as well as a large variety of parts for the machine tool and textile machines are manufactured. In addition to the usual machining departments, there are heat treating, chrome plating, and hydraulic assembly departments.

Following a steak dinner at the Reeves Hotel, several company representatives answered questions and further described the operations. Chairman Bob Jones presided at the short business meeting. Fred Benco of the Warner & Swasey Co. had a large part in making this an enjoyable plant tour.

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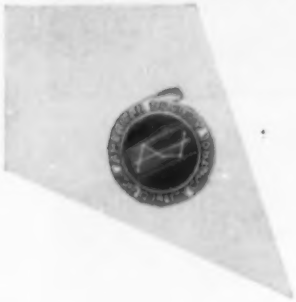

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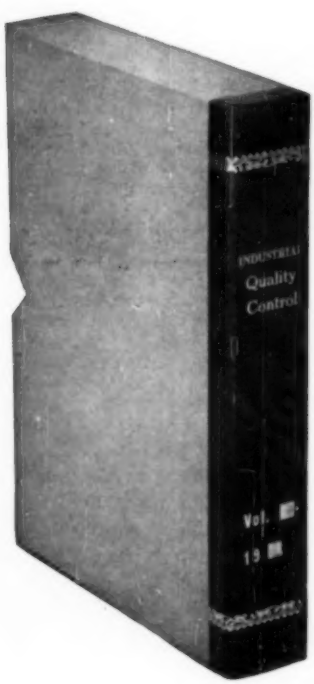

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SIGNIFICANT DIFFERENCES

. . . Allentown-Bethlehem—Dave Hilder spoke before the professional group of reliability and QC of the Philadelphia chapter of IRE.

Bonnie Small conducted training courses at the 13th Midwest QC conference held recently in Kansas City, Mo.

. . . Chicago—We are sorry to report that Martin Joseph, American Hospital Association, is leaving the section. But we are happy to report that he has a very good position waiting for him in Sunnyvale, Calif. as senior research engineer with Lockheed Aircraft Corp.

. . . Cincinnati—John M. Scanlon has recently been appointed as manager of quality of the manufacturing section, production engine dept., aircraft gas turbine division of General Electric Co., Evendale, Ohio.

Judson H. Wiersemer transferred from the Grand Rapids section. He is now employed as quality engineering specialist with General Electric Co.

Harry T. Rutter, Jr., has transferred from the Cleveland section. He is now employed by G. E., flight propulsion laboratory dept.

A transfer from Detroit has brought Kai Jacobsen to our section. He is employed as chief brewmaster for the Geo. Wiedemann Brewing Co., Newport, Ky.

. . . Cleveland—The members of the section were able to read with pleasure an article by member Bertrand L. Hansen in the December issue of **TOOLING AND PRODUCTION.** Bert's paper was entitled "Reduce inventories and cut backorders."

A most successful educational program of six two-hour sessions on the analysis of variance has been completed by Harry Wadsworth of Western Reserve University. The session was so well received that the section has decided to sponsor another advanced training program this spring. Details may be obtained from Harry Wadsworth, Statistics Dept., Western Reserve University.

. . . Dallas-Fort Worth—Our thanks to Robert P. Bosche, Chance Vought Aircraft for an excellent job of planning and instructing a most successful basic course in SQC. A total of 57 enrolled in the course—51 of these attended six of the eight courses thus earning certificates and 19 of these had 100 percent attendance. The section gained 34 new members through this course.

. . . Harrisburg—J. Howard Johnson has accepted a position with Raytheon Mfg. Corp. and has transferred his membership to the Boston section.

. . . Hartford—Sid Clark has accepted the position of senior QC engineer for M & C Nucelar, Inc., Attleboro, Mass. Sid had been associated with the Torrington Co. for nine and one-half years, the last three and one-half as their QC manager.

. . . Phoenix—M. Maggiano has recently assumed a QC engineering position with the Phemco Corp.

Our congratulations to A. R. Pennel, section past chairman, who has recently assumed the responsibility for all QC activities at the Motorola Western Military Dept.

Our congratulations also, to Dr. John Fruend, section vice chairman, who has recently been appointed head of the mathematics dept., Arizona State University.

. . . Pittsburgh—William I. Martin was promoted to manager of the statistical design group, Koppers Co., Inc., Verona Research Center.

Frank G. Mediats, has joined the Westinghouse Corp. as a supervisor of QC.

John Hromi, section president, was chairman of the design of experiments session at the national meeting of ASA held in Chicago.

P. Whidden, W. Goepfert, and D. McCune attended the Princeton conference on process developments by statistical methods.

. . . Portland—Welcome to new members "Casey" Hokestra and Ruth Jones of Omark Industries.

In the December issue, we reported Bob Menstell as being with the American Can Co. Our error—Bob is doing an excellent job at Osborne Electronics and is not leaving.

. . . Salt Lake City—Dr. H. E. Flanders, who is section educational chairman, was recently featured with a picture and an article in the daily **DESERT NEWS AND TELEGRAM** of Salt Lake City.

Henry Matis, chairman of the membership committee, recently completed a three-week course at the Air Force Institute of Technology at Dayton, Ohio.

. . . San Francisco Bay Area—Roy A. Wylie has joined Ampex Corporation's quality control division as manager of the instrumentation products QC department. Mr. Wylie is a Fellow of the Society and is currently editor of the "What's New?" department of **INDUSTRIAL QUALITY CONTROL.**

. . . Syracuse—George Lamoy has accepted a new position as analytical chemist and statistician in the control laboratory section of the Thiokol Corp., Elkton, Md.

Hugh Wallace started new duties on Dec. 1 at Cornell University. He is now engineer psychologist working in human factors at the advanced electronics center.

. . . Tennessee—Lee Herndon's daughter, Ann, was married on Dec. 27 to Robert Hoeke of Knoxville. Mr. Hoeke is an instructor at the University of Tennessee.

We are sorry to lose James S. Evans who transferred Jan. 1 to become mill manager of a Mead Corp. plant in Ohio. Best wishes go with you from all section members.

. . . Tulsa—We are sorry to hear that Mr. Browers is moving to Little Rock, Ark.

It is a pleasure to welcome Mr. Davison of Phillips Petroleum into our section.

clinics, conferences, and courses

MARCH

. . . **5-6**—Statistical Methods Engineering Institute, The University of Wisconsin, Madison, Wis., contact Engineering Institutes, University Extension Division, The University of Wisconsin, Madison 6, Wis.

. . . **7**—Sixth Annual QC Forum, Hart House, University of Toronto, sponsored by the Toronto section of ASQC.

. . . **11-12**—9th Annual Iron & Steel Conference, Pittsburgh, Pa., sponsored by the Pittsburgh section of ISA, contact R. E. Blackwell, Pittsburgh Section ISA, Box 1346, Pittsburgh 30, Pa.

. . . **12**—All-Day Conference, Chamber of Commerce, Ft. Wayne, Ind., sponsored by the Northeastern Indiana section of ASQC.

. . . ***14—Second National Conference, University of Michigan, Ann Arbor, Mich., co-sponsored by Automotive Division and Greater Detroit section of ASQC.***

. . . **20**—Sixth Industrial Clinic for QC, Wisconsin Hotel, Milwaukee, Wis., (all-day conference with four simultaneous sessions of SQC applications to management, engineering, and inspection), sponsored by the Milwaukee section of ASQC in cooperation with the Wisconsin Manufacturers' Association.

. . . **21**—Joint 5th District Industrial QC Conference, Hotel Traylor, sponsored by the Allentown-Bethlehem section of ASQC.

. . . **26**—15th Annual Clinic, University of Rochester, Rochester, New York, sponsored by the Rochester section of ASQC.

APRIL

. . . **3-4**—7th Northwest Conference for QC, Portland, Ore., sponsored by the Portland section of ASQC.

. . . **5-10**—1959 Nuclear Congress, Public Auditorium, Cleveland, Ohio, contact Engineers Joint Council, 29 West 39th St., New York 18, N. Y.

. . . **18-22**—ASTE Annual Meeting, Schroeder Hotel, Milwaukee, Wis., sponsored by ASTE, contact Harry E. Conrad, ASTE, 10700 Puritan Ave., Detroit 38, Mich.

BOOK REVIEWS

W. D. Baten, Editor

26 University Drive, East Lansing, Mich.

MOTION AND TIME STUDY (Fourth Edition) by Ralph M. Barnes, published by John Wiley and Sons, Inc., New York, N.Y., 665 pages, $9.25. Reviewed by James M. Apple, Industrial Management Consultant, East Lansing, Michigan.

Probably the most widely used text in the field, Barnes' *Motion and Time Study* has recently appeared in a new fourth edition. Long a favorite for college and university use, this profusely documented presentation of motion and time study has become the "standard" reference source in the field.

An outstanding feature of this book has always been the large number of examples and illustrations. The 665 page book contains 356 figures and 81 tables! Also included is an exhaustive bibliography of over 350 works of interest in motion and time study.

Besides covering the "basics" of motion and time study, Professor Barnes has included such related topics as:

- Motion Study, Mechanization, and Automation
- Written Standard Practice
- Mechanized Time Study and Electronic Data Processing
- Work Sampling
- Motion and Time Study training programs
- Training the Operator

Two appendices present a sample time study manual and a wage incentive manual.

It is the reviewer's opinion that this book is *the* most complete text reference on motion and time study. It is sincerely recommended that anyone even remotely interested in the field should have this book in his library. It should be unbelievable if even the most casually interested person were not able to pick up a handful of useful ideas for application to his field of work.

MILL TEST PROCEDURES by N. L. Enrick, Modern Textiles Magazine and Rayon Publishing Company, New York, pages 5-54, price $3.50. Reviewed by Oliver Beckwith of the William Carter Company.

This is a manual describing test methods that can be used in process quality control work in textile manufacturing. Primary emphasis is on cotton goods manufacturing; however, woolen yarn and hosiery manufacturing are touched on. The operations covered include opening, spinning, slashing, weaving and knitting. For each of the processes covered, a background discussion of the purpose of performing the tests is given. The frequency of sampling at each process point is given; the recommendations for recording and evaluating the data as well as the detailed description of the text technique are included.

The statistical analysis and interpretation of test data is not covered in this handbook. This is to be found in a companion manual by the same author entitled, *Quality Control Through Statistical Methods.*

MILL TEST PROCEDURES should be very useful to anyone initiating a quality control program in a textile mill. The experienced textile quality control man will find it a helpful source of ideas and techaiques. A point not emphasized by the author is that much of the basic work in the development of textile test methods including a number of those described in the HANDBOOK, comes from the work of the American Society for Testing Materials and the American Association of Textile Chemists and Colorists. The beginner in textile quality control should be advised to keep in touch with the work of the two societies and, if possible, join them and contribute. The author has done a service for the industry in preparing this manual.

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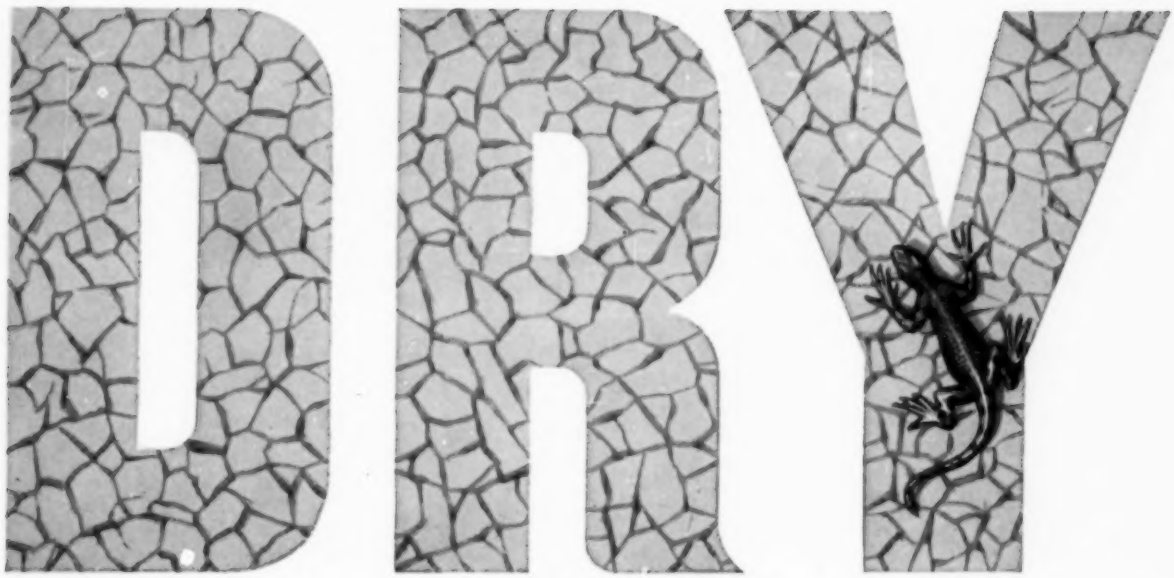

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